AD-A086 864 DOUGLAS AIRCRAFT CO LONG BEACH CA F/G 1/2
EVALUATION OF THE IMPACT OF TOWING DC-9 TRANSPORT AIRPLANES AT --ETC(U)
MAY 80 E A HOOVER DOT-FA78WA-4198

UNCLASSIFIED FAA-NA-80-23 NL

1 of 2
AD
A086864

Report No. FAA-NA-80-23

(12) LEVEL II

EVALUATION OF THE IMPACT OF TOWING DC-9 TRANSPORT AIRPLANES AT BOSTON-LOGAN AIRPORT

E. A. Hoover

Douglas Aircraft Company
Long Beach, California 90846

FINAL REPORT

MAY 1980

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City, New Jersey 08405

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Technical Report Documentation Page

1. Report No. FAA-NA-80-23	2. Government Accession No. AD-A086 864	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of the Impact of Towing DC-9 Transport Airplanes at Boston-Logan Airport		5. Report Date May 1980
		6. Performing Organization Code
7. Author(s) E. A. Hoover		8. Performing Organization Report No.
9. Performing Organization Name and Address Douglas Aircraft Company McDonnell Douglas Corporation 3855 Lakewood Boulevard Long Beach, California 90846		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOT-FA78WA-4198
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Washington, D. C. 20591		13. Type of Report and Period Covered Final Sept 78 - Oct 79
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report summarizes an investigation to determine the impact of the proposed revisions to airport rules at Boston-Logan International Airport regarding ground movement of aircraft by towing in lieu of taxiing as it affects the fatigue life of the DC-9 aircraft.

Tests were conducted using an instrumented tow bar to determine the range of loads which could be expected to occur in service. These loads were then incorporated into a loads model which represents the Boston-Logan towing regime. This loads model was then utilized to perform analysis on the DC-9 nose landing gear and its support structure to determine the fatigue effects. Cost estimates of additional testing, inspection and replacement of affected parts is provided.

The results of this investigation indicate that several nose landing gear components could be seriously affected depending upon the degree of exposure to the additional towing at Boston and the number of flights already accumulated by the part at the time the additional towing is initiated at Boston. The immediate effect on these components could be minimized by a redistribution of aircraft within the airline fleet to reduce the exposure of high-time parts to the Boston towing regime.

17. Key Words Towing - Aircraft	18. Distribution Statement This document is available to the U. S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	128	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

(18) (19) (6) (10) (15) (11) (12) 120 (9) Final rept. 116400

PREFACE

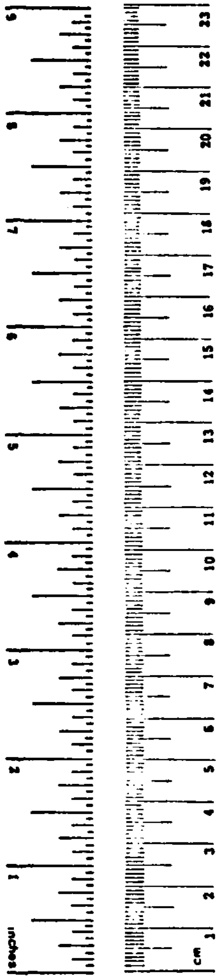
This study was conducted by and report prepared by the Douglas Aircraft Company, a Division of McDonnell Douglas Corporation, under a contract for the Federal Aviation Administration of the Department of Transportation. Technical monitors for the Federal Aviation Administration were Mr. H. V. Spicer and Mr. V. G. Sanborn. Acknowledgement is made to Eastern Airlines Personnel for their assistance during observations of operations at Boston-Logan Airport.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

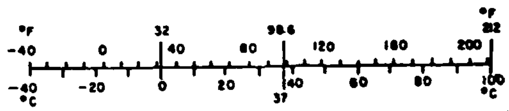


TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF FIGURES

LIST OF FIGURES - Continued

LIST OF FIGURES - Continued

LIST OF FIGURES - Continued

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

AF	N-A	Load condition "A", maximum load level, normal aft towing
AT	N-A	Load condition "A", minimum load level, normal aft towing
BF	N-F	Load condition "B", minimum load level, normal forward towing
BT	N-F	Load condition "B", maximum load level, normal forward towing
CF	M-A	Load condition "C", maximum load level, moderate aft towing
CT	M-A	Load condition "C", minimum load level, moderate aft towing
DF	M-F	Load condition "D", minimum load level, moderate forward towing
DT	M-F	Load condition "D", maximum load level, moderate forward towing
EF1	H-A	Load condition "E", maximum load level, hard aft towing
EF2	H-A	Load condition "E", minimum load level, hard aft towing
EF3	H-A	Load condition "E", maximum load level, hard aft towing
ET	H-A	Load condition "E", minimum load level, hard aft towing
FF1	H-F	Load condition "F", minimum load level 1, hard forward towing
FF2	H-F	Load condition "F", minimum load level 2, hard forward towing
FT	H-F	Load condition "F", maximum load level, hard forward towing
K_F		Factor applied to the calculated stress level in order to produce cumulative damage of unity for a given number of flights
MAC		Mean aerodynamic chord
PSI		Pounds per square inch

INTRODUCTION

The Massachusetts Port Authority has proposed airport rules and regulations in response to petitions to reduce noise. (Ref. Appendix A) In these rules, prohibitions on self-propelled aircraft operating movements are mandated within the south and southwest terminal apron and taxiway area as indicated in figure 1. Compliance with these regulations is proposed by the operational towing of arriving and departing aircraft within the designated areas.

On the surface, one logical solution would seem to be to have aircraft towed in lieu of operating under their own power. These additional towing operations could, however, induce severe fatigue related problems for the nose gear and its supporting structure. The purpose of this report is to investigate the effect of the additional towing, as proposed at Boston-Logan, as it concerns the Douglas DC-9 and make recommendations which will ensure safe operation of the DC-9 aircraft.

It is important to recognize that the DC-9 was originally designed as a small maneuverable transport which would require very little ground support equipment. As a consequence the DC-9 was considered to be an airplane which would not require extensive towing. For this reason, a complete study of the effects of additional towing, such as proposed at Boston-Logan, is considered essential to ensure the safety of DC-9 operations.

This report determines the effects on the fatigue life of the DC-9 nose landing gear and supporting structure resulting from operational towing such as proposed at Boston-Logan International Airport. This report provides for incorporating the additional loading cycles due to towing operations, as proposed at Boston-Logan, into an overall loads model which describe the towing environment of the DC-9. Recommendations are made, as to structural modifications, inspections, maintenance or operating procedures and limitations which can reasonably be instituted to ensure the safety of the DC-9 subjected to the proposed towing operations.

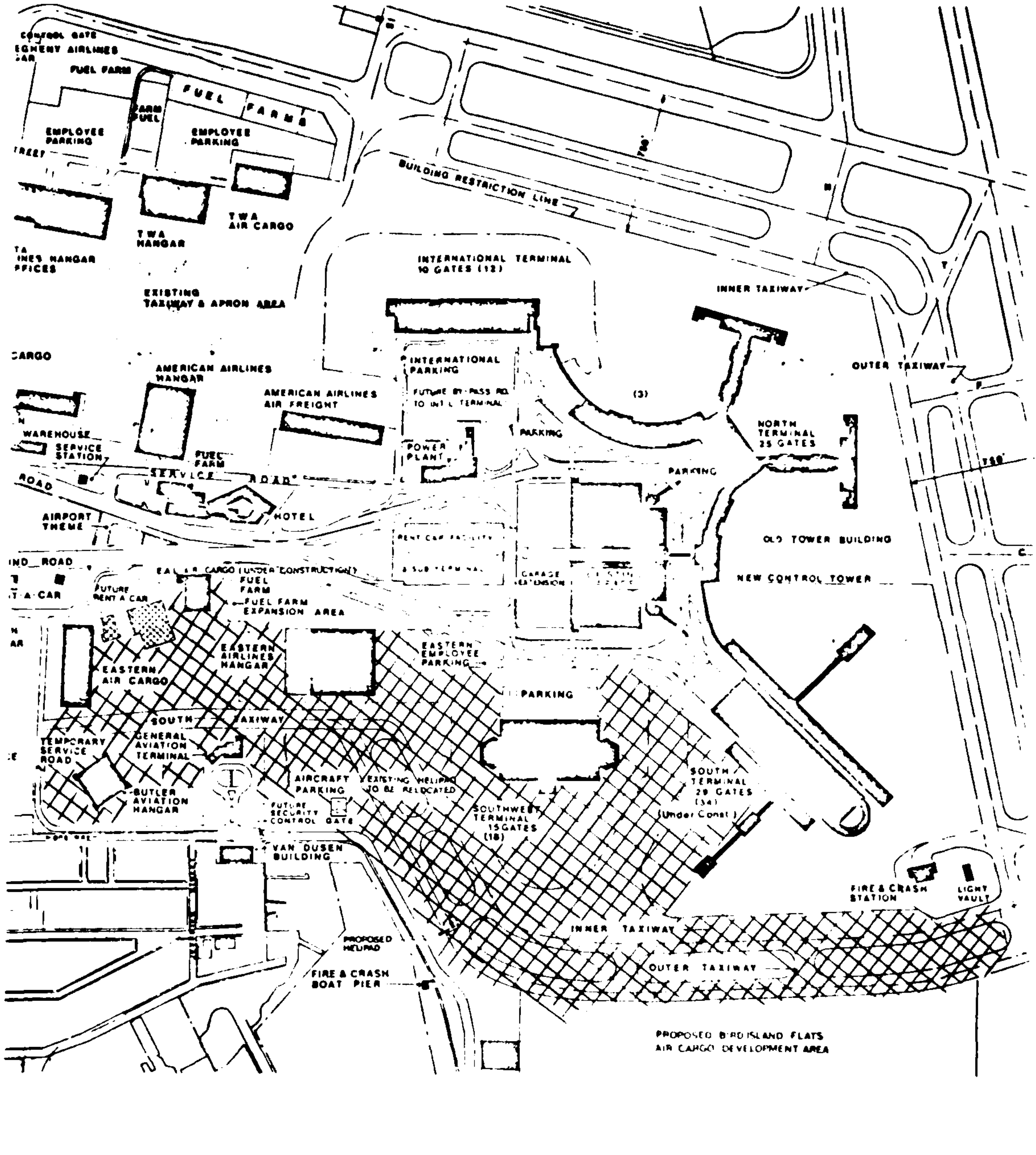


FIGURE 1. PROPOSED TOWING AREA AT BOSTON-LOGAN AIRPORT

Measurement of tow loads were made in order to obtain parametric data which can be applied to any towing operation at any airport. Observations of powered operations at Boston-Logan were conducted in order to provide data on typical aircraft maneuvers. Towing loads were measured under a variety of conditions in order to provide a range of tow loads which could be expected to occur in service.

Loads models were considered for three operational modes. These models represent towing during various time periods. The differences in the models used in the original design and the new loads models are discussed. The loads models are then used to determine the fatigue critical structural components and analyses are carried out in order to provide recommendations as to the options available to ensure safe operation of the DC-9.

Special consideration is given to new and inovative concepts in tow vehicles and tow bars and the economic impact of the available options is provided.

TESTING

In order to conduct a meaningful test program, observations of operations at Boston-Logan International Airport were conducted. These observations were accomplished on November 19, 20 and 21, 1978. Included in the observations were typical push-out maneuvers, distance required to taxi, turns, and towing for maintenance purposes. Most of the observations were conducted at the Eastern Airlines Terminal. Eastern Airlines was extremely cooperative in permitting observations. Informal discussions were held with maintenance personnel in order to gain a feel for actual towing procedures. During several towing operations Douglas Engineers accompanied Eastern Airlines personnel in order to gain first hand knowledge of towing procedures. In addition to observing the existing towing procedures particular attention was given to the additional towing which would be required to perform the maneuvers now conducted under power. In this same context congestion was studied at various times of the day in order to determine the typical number of starts and stops which would be required during towing in the designated area.

All testing to obtain towing loads was accomplished at Long Beach Municipal Airport and the Douglas Aircraft Facility, Long Beach, California as indicated in Figure 2. The testing was accomplished using a DC-9 Series 40 aircraft at a gross weight of 100,000 lbs and a center of gravity position of 9% MAC. The aircraft weight and center of gravity position was not varied during the test. Since the tow force required to push or pull the aircraft is directly related to the coefficient of friction at the tire ground interface, the tow force is considered to be directly proportional to the aircraft gross weight. The variation in aircraft center of gravity would merely redistribute the aircraft weight between the main and nose gears but would not affect the overall tire ground interface.

The tow vehicle was a United Shop Mule weighing 22,380 lb with a rated constant pulling power of 16,200 lb. The vehicle is equipped with two forward and two reverse speeds. The transmission is a fluid drive with manual shift to the higher speed range. This tow vehicle is more than adequate for towing the DC-9 and has sufficient power to tow the DC-9 at speeds up to 15 knots.

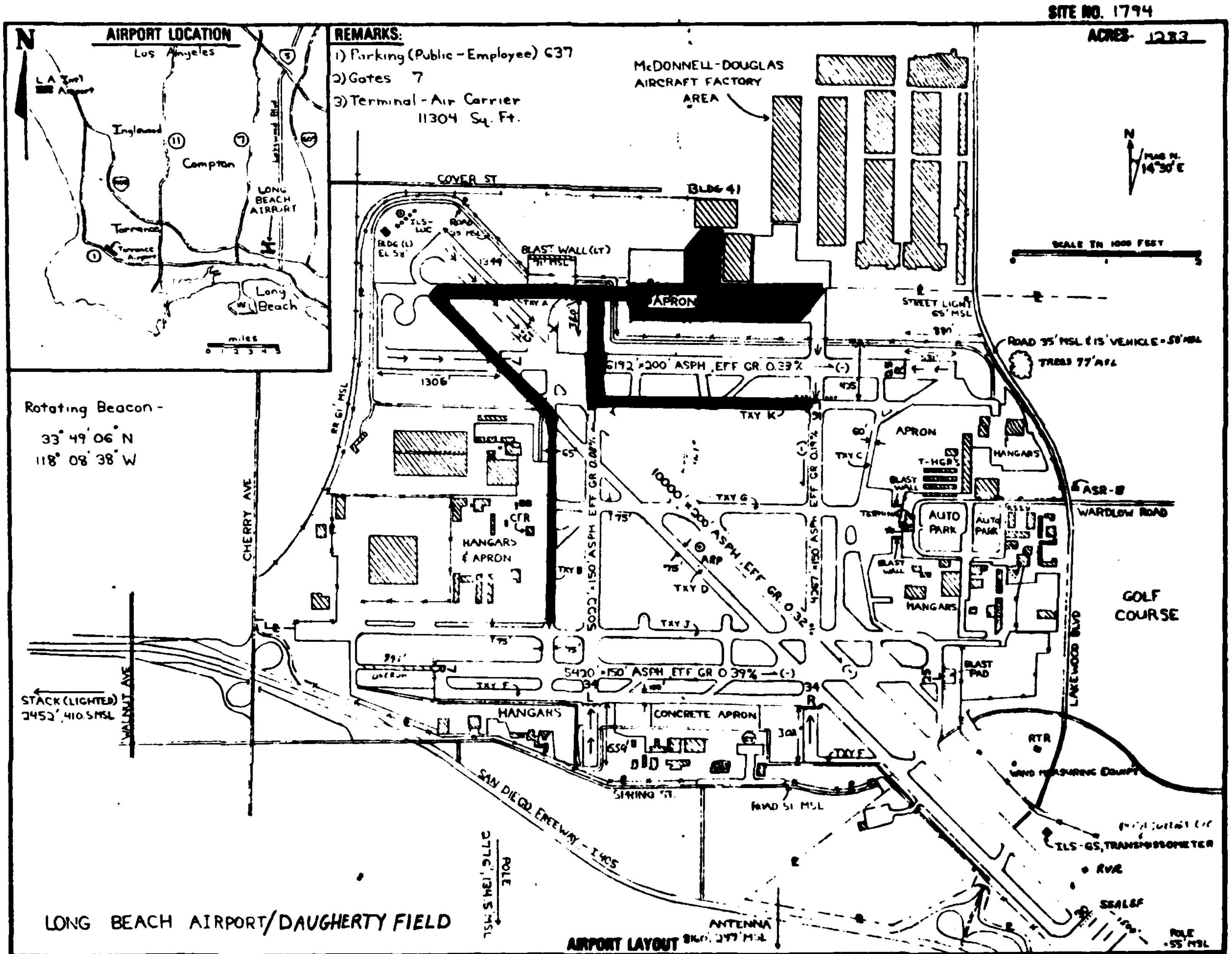


FIGURE 2. TOWING TEST AREA AT LONG BEACH

Communications were maintained between the tow vehicle and aircraft crew. The aircraft crew did not apply aircraft brakes at any time during the test. Application of aircraft brakes during towing is extremely hazardous and is to be considered only in extreme circumstances. Serious damage could be incurred by the nose gear due to aircraft braking and therefore braking by the aircraft crew was ruled out as a test variable.

The aircraft was considered to be in the normal serviced condition with tire pressures and landing gear servicing as required by the maintenance manual. Normal variations in tire pressures and landing gear strut extensions are not considered significant enough to affect the test results.

The weather conditions on the day of the test were generally overcast with partial clearing in the afternoon. The temperature was in the low 60's and the winds were light. Winds of moderate force are not considered to significantly affect towing loads for the DC-9. Winds of considerable force are accounted for during the development of the loads models.

The tow bar used during testing was of a rigid type. This type tow bar is essentially the same as currently in use by Eastern Airlines at Boston-Logan. There are currently no tow bars available for the DC-9 which incorporate a shock absorbing device.

An aluminum insert for the tow bar was designed and manufactured in order to obtain the necessary sensitivity for the strain gage installation. The insert was instrumented to record axial load and side bending in the tow bar. In addition, the steering angle of the nose gear was recorded during the test. The ground speed as indicated by the inertial navigation system was noted during testing by the flight test engineer.

The data was recorded on board by a six channel pen recorder for real time data acquisition in order to provide information necessary to alter the test procedure should a potential damaging condition occur. In addition, the data was recorded continuously by means of a wide band one-inch tape recorder. The tape recorded data was then processed at the Douglas Long Beach Facility using the computing and graphic display capabilities of the Douglas Flight Data Center. The Flight Data Center is equipped with a XDS Sigma 7 digital computer, five Sanders ADD/960 graphic data display stations and the necessary peripheral equipment.

All towing was conducted on asphalt surfaces. Both wet and dry surfaces were investigated. Dry tests were accomplished using taxiways A, B, D and the apron area of the Douglas Aircraft Facility as indicated in Figure 2. The wet tests utilized taxiway K and the Douglas apron. Long Beach airport taxiways A, B, D and K are essentially level. The Douglas apron is also level except for a portion directly in front of Building No. 41. This area was used to investigate towing on slopes. The slope in this area varies to 1.75% with an average slope of approximately 1.25% in the area used for testing.

The towing tests were conducted under a variety of conditions. The aircraft was towed over the gate tracks which enclose the Douglas Aircraft Facility to provide data for towing over a "rough" surface. Runway and taxiway intersections were traversed. The aircraft was pushed back with varying degrees of force from light to hard. Forward towing was accomplished with light to hard jerks. Light to heavy tow vehicle braking from speeds of up to 14 knots was investigated. All tow vehicle braking and jerking maneuvers were repeated on wet asphalt.

Towing on a sloping surface was investigated utilizing the area immediately in front of Building 41 of the Douglas Aircraft Facility as previously mentioned. Various maneuvers of pull-up, push-down, push-up and pull-down were accomplished on both wet and dry asphalt.

In order to simulate apron and taxiway surfaces which become ice and snow covered forming bumps and ruts, the aircraft was towed over one-inch thick plywood sheets. The simulated bumps were not intended in any way to simulate the friction characteristics of ice and snow but merely to provide data as to the towing loads required to pull or push the aircraft out of a rut or over a thick patch of ice or snow. The boards were placed directly behind the nose gear and alternately the main gear and the loads required to push the aircraft over the "bump" recorded. Similarly the boards were placed in front of the nose and main gears and the aircraft pulled over the boards. Loads required to tow the aircraft over the bumps at slow and moderate speeds were also recorded.

The results of the towing tests indicated that the only significant loads occurred during starting and stopping. Steady state towing produced tow bar loads of one to three percent of the aircraft gross weight. No significant increase in this steady state load occurred during towing over runway and taxiway intersections. Towing over a "rough" surface produced loads equal to or less than those experienced during normal pull out or push-in maneuvers. Peak loads during normal push-out and pull-in maneuvers were on the order of five percent of the aircraft gross weight. Moderate braking by the tow vehicle produced loads of approximately eight percent of the aircraft gross weight. Heavy tow vehicle braking resulted in loads of twelve percent of the aircraft gross weight and in some cases higher loads were recorded. Little difference was noted between loads recorded on wet and dry surfaces. Towing loads required during maneuvers conducted on a sloping surface were generally seven percent of aircraft gross weight as opposed to five percent of aircraft gross weight on a level surface.

Appendix B contains time history plots of the loads encountered during the various towing maneuvers conducted.

LOADS MODELS

Three loads models were investigated. One model depicts 24 hour per day towing in the designated areas of Boston-Logan. The second depicts 12 hours per day towing from 7:00 PM to 7:00 AM in the designated areas and the third model depicts one one-way tow per day from midnight to 6:00 AM.

Careful consideration was given to the three loads models presented and one loads model was selected which in effect includes all three. Current schedules of Eastern and Allegheney Airlines indicate that no DC-9 operations are conducted between the hours of midnight and 6:00 AM. This in effect, eliminates one loads model. The number of DC-9 operations between the hours of 7:00 PM and 7:00 AM is approximately 20% of all DC-9 operations by Eastern and Allegheny during a typical day. Beyond these considerations the need to develop specific loads models for specific aircraft during specific times of the day does not appear to be a viable approach.

Since the aircraft in question fly to other airports where extensive towing is not required a more logical approach would seem to be to develop a loads model which would provide the load environment experienced by a particular aircraft based upon the percent of time that aircraft is required to be towed at Boston. That is to say if an aircraft flies into Boston every fourth flight it would accrue half the fatigue damage associated with the Boston towing regime as an aircraft which flies into Boston every second flight (i.e. shuttle aircraft). Aircraft which arrive and depart Boston during hours in which towing is not required would be considered as not operating at Boston.

Using this approach, it is relatively easy to determine the effect of the Boston towing requirement on the fatigue life of nose landing gear components not based upon the various time periods in which towing is required but merely on whether or not the aircraft in question operates at Boston during those time periods. This in effect provides one loads model which includes all three. All that is of concern is the loads associated with the Boston towing and the number of occurrences of these loads for a particular aircraft. The number of occurrences would only depend on whether the aircraft is operated at Boston during the hours in which towing is required.

The actual loads used in the model are developed from those recorded during the towing tests. The terms "normal", "moderate" and "hard" are used to describe the various maneuvers. "Normal" maneuvers are those which are considered to occur under good weather conditions and in which no abrupt maneuvers are performed. These maneuvers would be perceived as normal by passengers in the cabin. "Moderate" maneuvers are those maneuvers which occur during marginal weather conditions and include maneuvers in which inadvertent stops are made. These maneuvers would be perceived as "different or unusual" by passengers in the cabin. "Hard" maneuvers are those maneuvers which occur during adverse weather conditions in which control of the aircraft is difficult to maintain or situations in which evasive or abrupt action by the tow operator is required. These maneuvers would be perceived by the passengers in the cabin as objectionable.

In order to establish the percent of time each load regime, i.e., "normal", "moderate", or "hard" would be considered, consideration was given to the degree in which the maneuver would be felt in the cabin. To more fully appreciate the terms "normal", "moderate" and "hard", other ground maneuvers such as landing, braking and turning were investigated. It was discovered that on the average, maneuvers judged to be "normal" occurred 80% of the time, "moderate" maneuvers occurred 17% of the time and "hard" maneuvers occurred 3% of the time. In addition, an investigation of weather conditions at Boston, (Appendix C) indicate adverse weather conditions (snow, ice, high winds, etc.) occur about 3% of the time. These two items correlate well. It was therefore decided that the Boston towing loads model would consider "normal" loads for 80% of the time, "moderate" loads 17% of the time and "hard" loads 3% of the time.

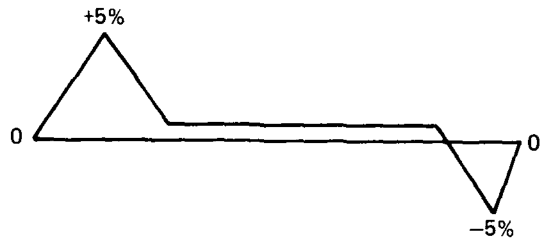
During the observations at Boston-Logan it was noted that during day to day push back operations it was not uncommon to stop before the push back was complete. This additional stop was required due to congestion and vehicular traffic. In effect, two tow cycles are occuring on some push-back maneuvers currently. Extensive observation of operations over a three day period at Boston-Logan concluded that a typical tow-out maneuver would require three start-stop cycles and a typical tow-in maneuver would require two start-stop cycles in the area in which towing would be required. Therefore the loads model considered for Boston-Logan towing consists of axial tow bar loads of 5% of aircraft gross weight occurring 80% of the time, loads of 8% of aircraft gross weight occurring 17% of the time and loads of 12% of aircraft gross weight occurring 3% of the time as indicated in Figures 3, 4 and 5.

Figure 5 indicates an extra load reversal for the hard maneuvers. It was discovered during the towing tests that an extra load reversal occurred nearly every time a hard maneuver was conducted. For this reason the additional load reversal is included in the "hard" condition.

The loads considered thus far have only been axial tow bar loads. Loads associated with side bending of the tow bar are considered also. Reference is made to excerpts from the DC-9 maintenance manual, (Appendix D, Paragraph C) in which specific mention is made of placing the nose wheel steering bypass valve in the bypass position, making nose gear steering inoperative. It is essential that this be accomplished in order to avoid overloading the nose gear by torque loads.

With the bypass valve in the bypass position the nose gear is free to swivel. Side loads input by the tow vehicle simply steer the nose gear with the only reaction being the tire-ground interface. Side loads at the tow vehicle are small while turning the aircraft as indicated in Appendix B. The largest side loads at the two vehicle occur when the tow vehicle is braking to a stop. The torque loads developed during heavy tow vehicle braking are of the same order of magnitude as those encountered during static swiveling of the nose gear. The current fatigue criteria considers static swiveling to occur once per flight and since static nose gear swiveling is less likely to occur when

NORMAL PUSHBACK



NORMAL FORWARD TOW

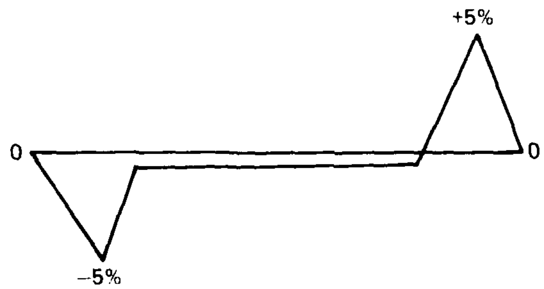
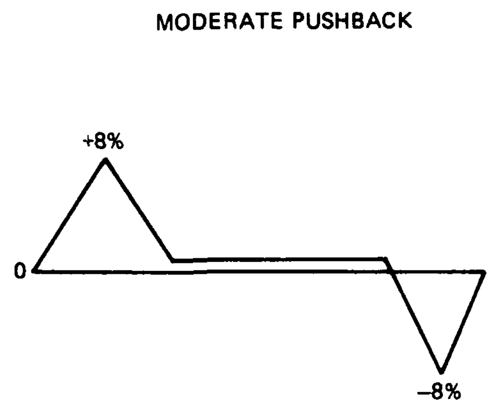


FIGURE 3. TOW FORCE ON NOSE GEAR AS A PERCENTAGE OF AIRCRAFT GROSS WEIGHT (POSITIVE DRAG LOAD AFT)



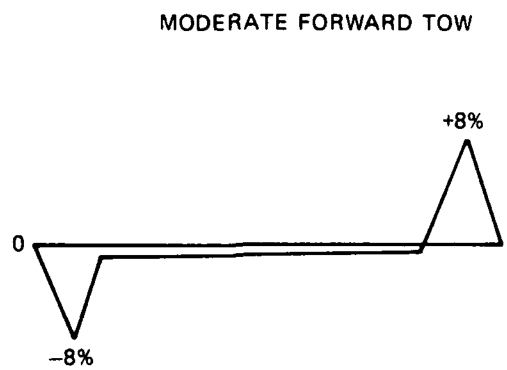
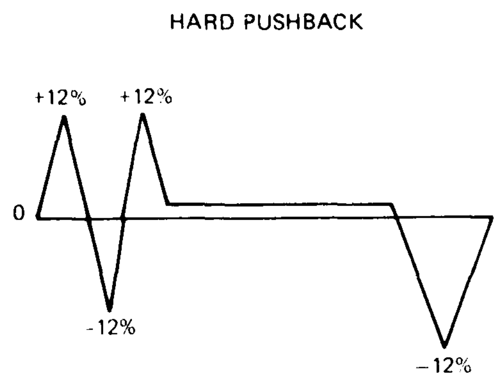


FIGURE 4. TOW FORCE ON NOSE GEAR AS A PERCENTAGE OF AIRCRAFT GROSS WEIGHT (POSITIVE DRAG LOAD AFT)



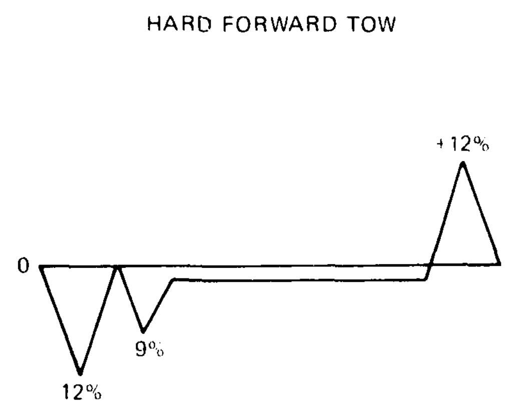


FIGURE 5. TOW FORCE ON NOSE GEAR AS A PERCENTAGE OF AIRCRAFT GROSS WEIGHT (POSITIVE DRAG LOAD AFT)

towing is in effect no additional fatigue damage is considered to occur due to induced side bending.

The loads throughout the nose gear structure due to the towing loads are determined by use of Douglas Computer Program G4TA. This program is capable of obtaining loads in all major nose gear components for any combination of loads input at the ground or axle. In addition the program considers gear deflections due to the loading and includes these secondary effects. The program is currently used by the Douglas Aircraft Compnay in determining loads in the nose and main gears of the DC-8, DC-9 and DC-10 aircraft.

All start stop cycles are considered to occur when the nose gear is in its centered position. This is considered to be a conservative assumption since as the steering angle increases loads in the nose gear drag brace system decrease as indicated in Figure 6.

This towing loads model, thus defined, differs substantially from that used to determine life limits of DC-9 gear components submitted in the type certification data. As mentioned in the introduction, the DC-9 was designed as a small maneuverable aircraft which would not require extensive ground support equipment. For this reason the original fatigue criteria considered a tow load of 5% of the aircraft gross weight occurring every other flight.

The aircraft gross weights used for each model are the same as used in the original analysis. Each DC-9 model had several mission profiles defined in the original analysis. These mission profiles consisted of a specific take-off gross weight, C.G., payload, and landing gross weight. Towing loads were obtained for each of these profiles. The towing condition used in the analysis was a "lumped" condition which included all the cycles of all the profiles but resulted in only one condition. The aircraft gross weight associated with this condition is used in this analysis. Only one gross weight is used for each DC-9 model even though the take-off weight is obviously higher than the landing weight. This weight is considered to be a typical weight associated with towing. The typical gross weight for the DC-9 Series 10 is considered to be 78000 lbs. The typical gross weight for the DC-9 Series 30

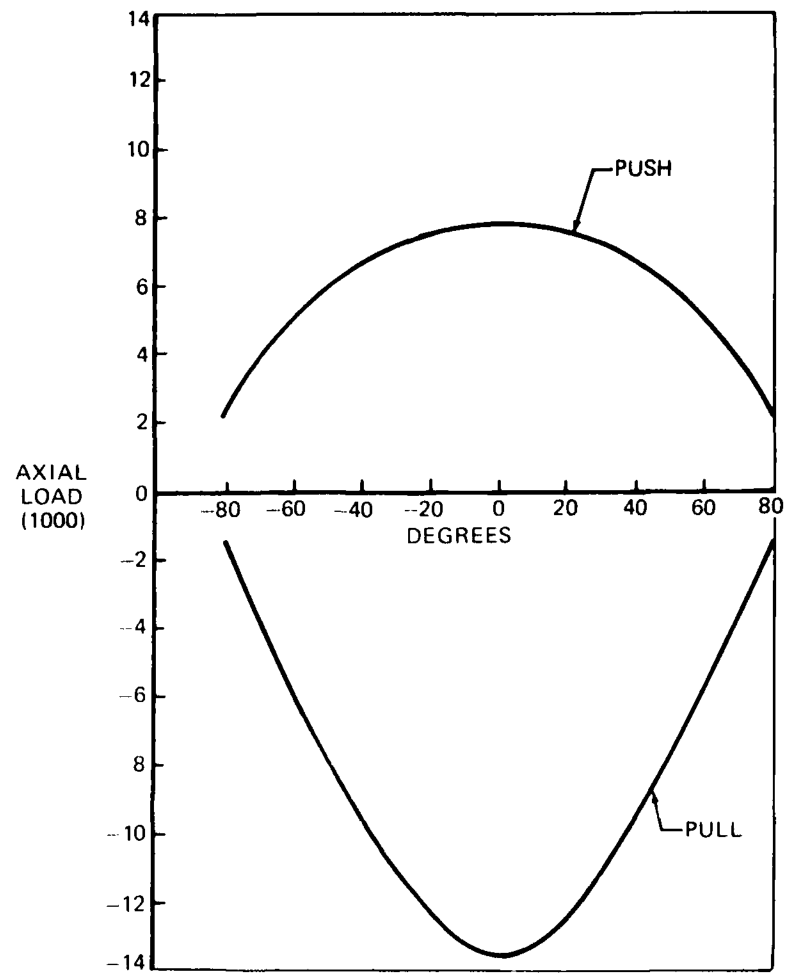


FIGURE 6. VARIATION OF DRAG BRACE AXIAL LOAD VERSUS TURNING ANGLE FOR CONSTANT TOW LOAD

is considered to be 90000 lbs and the typical gross weight for the DC-9 Series 50 is considered to be 102000 lbs.

The loading conditions used in this analysis for DC-9 Series 10, Series 30 and Series 50 are indicated in Tables 1, 2 and 3. The conditions represent the "normal", "moderate" and "hard" maneuvers. The vertical load applied to the nose gear is the same as used in the original analysis. The applied drag load represents the cyclic loading shown in Figures 3, 4 and 5.

TABLE 1

DC-9 SERIES 10 GROUND LOADS ON NOSE GEAR

AIRCRAFT WEIGHT = 78,000 LB
NOSE GEAR VERTICAL LOAD = 6000 LB
STRUT EXTENSION = 2.1 IN.

TYPICAL TOWING CONDITION USED TO ESTABLISH SERIES 10 LIFE LIMIT

CONDITION		DRAG LOAD (LB)	VERTICAL LOAD (LB)
AF	N-A	3900	6000
AT	N-A	–3900	6000
BF	N-F	–3900	6000
BT	N-F	3900	6000
CF	M-A	6240	6000
CT	M-A	–6240	6000
DF	M-F	–6240	6000
DT	M-F	6240	6000
EF1	H-A	9360	6000
EF2	H-A	–9360	6000
EF3	H-A	9360	6000
ET	H-A	–9360	6000
FF1	H-F	–9360	6000
FF2	H-F	–7020	6000
FT	H-F	9360	6000

TABLE 2
DC-9 SERIES 30 GROUND LOADS ON NOSE GEAR

AIRCRAFT WEIGHT = 90,000 LB
NOSE GEAR VERTICAL LOAD = 8310 LB
STRUT EXTENSION = 2.2 IN.

TYPICAL TOWING CONDITION USED TO ESTABLISH SERIES 30 LIFE LIMIT

CONDITION		DRAG LOAD (LB)	VERTICAL LOAD (LB)
AF	N-A	–4,500	8310
AT	N-A	4,500	8310
BF	N-F	–4,500	8310
BT	N-F	4,500	8310
CF	M-A	7,200	8310
CT	M-A	–7,200	8310
DF	M-F	–7,200	8310
DT	M-F	7,200	8310
EF1	H-A	10,800	8310
EF2	H-A	–10,800	8310
EF3	H-A	10,800	8310
ET	H-A	–10,800	8310
FF1	H-F	–10,800	8310
FF2	H-F	–8,100	8310
FT	H-F	10,800	8310

TABLE 3

DC-9 SERIES 50 GROUND LOADS ON NOSE GEAR

AIRCRAFT WEIGHT = 102,000 LB
NOSE GEAR VERTICAL LOAD = 7900 LB
STRUT EXTENSION = 2.0 IN.

TYPICAL TOWING CONDITION USED TO ESTABLISH SERIES 50 LIFE LIMITS

CONDITION		DRAG LOAD (LB)	VERTICAL LOAD (LB)
AF	N-A	5,100	7900
AT	N-A	–5,100	7900
BF	N-F	–5,100	7900
BT	N-F	5,100	7900
CF	M-A	8,160	7900
CT	M-A	–8,160	7900
DF	M-F	–8,160	7900
DT	M-F	8,160	7900
EF1	H-A	12,240	7900
EF2	H-A	–12,240	7900
EF3	H-A	12,240	7900
ET	H-A	–12,240	7900
FF1	H-F	–12,240	7900
FF2	H-F	–9,180	7900
FT	H-F	12,240	7900

ANALYSIS

The nose landing gear of the DC-9 consists of a piston-axle assembly, cylinder assembly, housing assembly and drag brace assembly as shown in Figure 7. The gear retracts forward into the wheel well with the drag brace assembly folding at the upper and lower brace attach point. Ground loads on the gear are reacted at the trunnion points of the housing and at the attachment of the upper drag links to the fuselage.

The nose gear for all models of the DC-9 has remained essentially unchanged. Some components have been strengthened but the geometry has remained unchanged. This analysis will be concerned with the DC-9 Series 10, Series 30 and Series 50 since these are the only models currently operated by Eastern and Allegheny Airlines at Boston-Logan Airport.

Of primary concern in the analysis is the drag brace structure. Drag loads at the ground or axle provide the most adverse loading for the drag brace system. The drag brace system consists of the upper and lower braces and their associated attaching hardware. Of secondary concern is the housing in the area of the lower drag brace attach, the axle and the fuselage support structure. Previous fatigue and safe life analyses indicate that these are the components adversely affected by towing loads.

The safe life limits of the nose landing gear components were determined in the original type certification data by means of fatigue tests and comparative analyses. The original DC-9 Series 10 nose landing gear was fatigue tested to an equivalent of three life times (120,000 flights). Included in this test spectrum was 60,000 cycles of towing loads. These tow loads consisted of a push-pull cycle of 5% of the aircraft gross weight considered for the test. The push-pull cycle provided a complete reversal of tow bar load.

Subsequent models of the DC-9 were analyzed by comparison to the original fatigue test. This technique is referred to as comparative analysis. This

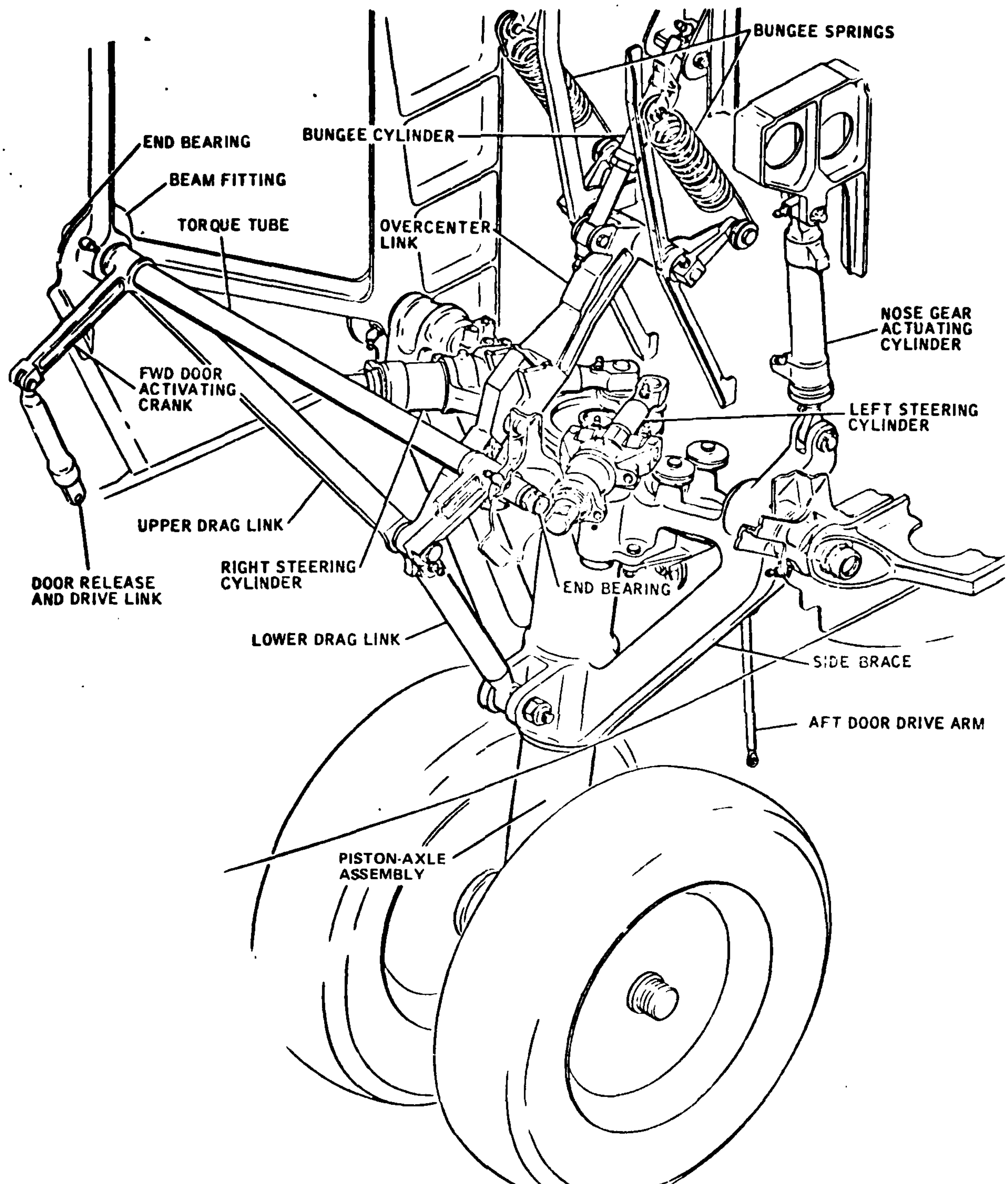


FIGURE 7. NOSE LANDING GEAR

analysis consists of considering the test part being analyzed as having accumulated enough fatigue damage at the conclusion of the original fatigue test to cause failure. A factor hereafter referred to as K_F, is determined which when multiplied by the test stress in the part for all conditions affecting the part produces a cumulative fatigue damage of unity. This procedure determines thre stress factor (K_F) to produce failure at the conclusion of the test. Miners hypothesis of cumulative damage is used in determining the fatigue damage by use of appropriate fatigue strength data. Once the factor has been determined for the test stresses it can be used for similar parts on other models of the DC-9. Applying the K_F factor to the stresses associated with other models of the DC-9 and taking into account changes in section properties and material properties, life limits for other DC-9 models can be established. All analysis is accomplished considering 120000 total flights and a scatter factor of three on cycles.

This procedure works well in most cases, however, the K_F determined sometimes turns out to be unrealistically large. In cases where the K_F is larger than three the fatigue stress is calculated by traditional means and multiplied by a factor of three. A factor of three on the calculated stress is considered to be extremely conservative, however in some lightly loaded parts a factor of three on the calculated fatigue stress can be tolerated. When a life limit is determined using a factor three on stress no scatter factor on cycles is incorporated.

These two methods of determining safe life limits were the only ones approved by the FAA. All DC-9 life limits currently in effect were determined by the afore mentioned techniques.

In the case of the Boston towing loads model, neither of these techniques worked well for several of the parts being analyzed. In these cases a "lead the fleet" concept was adopted. This concept simply considers high time aircraft as having successfully completed a test program in the field. In the case of the DC-9 Series 10 several individual aircraft have accumulated 40,000 flights or more as shown in Figure 8. Several Series 30 aircraft have accumulated 32,000 flights or more (Figure 9) and several Series 50 aircraft have

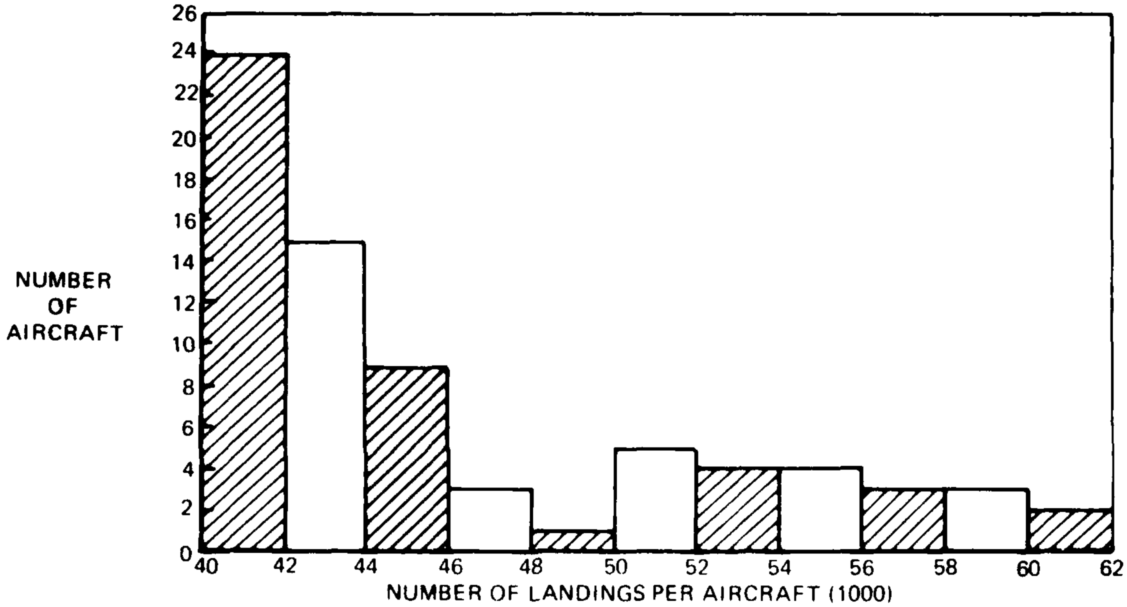


FIGURE 8. HIGH-TIME FLEET EXPERIENCE, DC-9 SERIES 10

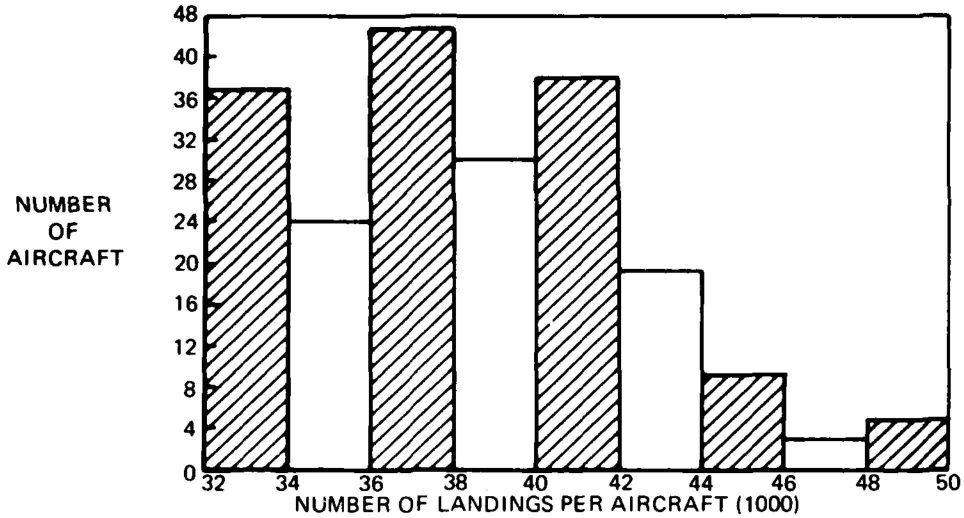


FIGURE 9. HIGH-TIME FLEET EXPERIENCE, DC-9 SERIES 30

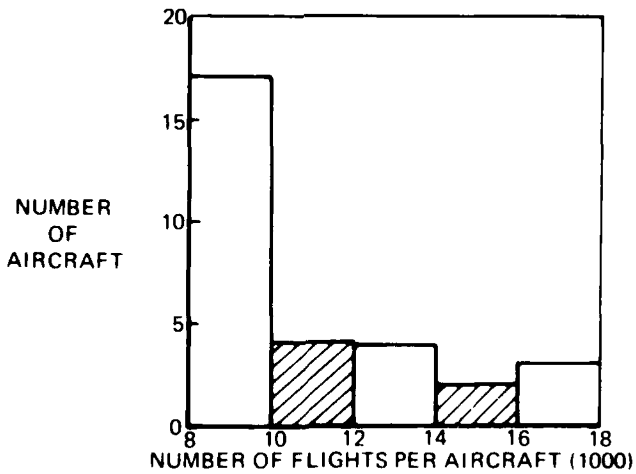


FIGURE 10. HIGH-TIME FLEET EXPERIENCE, DC-9 SERIES 50

accumulated 8000 flights or more (Figure 10). Considering that these high time aircraft are pushed-out from the ramp at least once per flight, and observations at Boston indicate that two start-stops occur often, and the loads experienced are the same as determined in this report then a test has been performed in the field under the loading conditions developed herein for push-back. The K_F is then determined using 40000 flights for the Series 10, 32000 flights for the Series 30 and 8000 flights for the Series 50. Once the K_F is determined it is applied to the loads model for the additional Boston towing. In other words, the fatigue life of the nose gear components are at least 40000 flights for the Series 10, 32000 flights for the Series 30 and 8000 flights for the Series 50, for the aircraft which have already experienced that number.

The 40,000 flights is used for the DC-9 Series 10. Whereas 32,000 flights is used for the Series 30 and 8000 flights used for the Series 50. It is felt that enough fleet experience has been gained for the various models at these number of flights to warrant basing the future life limit on this approach.

The basic assumption in this approach is that a Series 10 aircraft which has already accumulated 40000 flights at the time towing is initiated at Boston will have the K_F determined considering the Boston towing regime on <u>all</u> future flights. Since the existing fatigue criteria for the DC-9 considers 120000 total flights, 40000 are considered as push-back only, since 40000 push-back operations are assumed to have occurred, and 80000 considered in the Boston towing regime. The push-back and the Boston towing loads used are as determined by the loads model herein.

For all conditions contributing to the fatigue damage of the part being analyzed a K_F is determined which when multiplied by the stress in the part results in a total cumulative fatigue damage of unity for 120000 flights. A scatter factor of three is then applied and a life limit of 40000 flights is obtained. This procedure, in effect, considers a DC-9 Series 10 aircraft with 40000 flights as having no additional life available if towing on all subsequent flights is of the Boston type.

The K_F factor determined for a particular DC-9 Series 10 part is then applied to the similar Series 30 and Series 50 part. If however, the Series 10 K_F does not produce a life limit of at least [illegible] flights for a Series 30 with

32000 accumulated flights or a life limit of 8000 flights for a Series 50 with 8000 accumulated flights a new K_F is developed for these models using the same procedure as the Series 10.

The calculation of the K_F factor is accomplished by trial and error until the required number of flights is obtained using a scatter factor of three on cycles. However at no time is the K_F factor permitted to be less than 1.0. This would mean that the actual stress is less than the calculated stress. This procedure will produce a lower K_F for the Series 30 and Series 50 than for the Series 10. This lower K_F will not be applied to the Series 10 however. The fleet experience of each model is applied to each model. The Series 10 experience is used for the Series 10, the Series 30 experience for the Series 30 and the Series 50 experience for the Series 50. The exception to this is that the higher fleet experience of the Series 10 may be applied to the Series 10 and 30 and the higher fleet experience of the Series 30 may be applied to the Series 50. However the lesser fleet experience of the Series 50 may not be applied to the Series 10 and 30 and the lesser Series 30 experience may not be applied to the Series 10.

One item which must be considered in the analysis is the accumulated fatigue damage at the time towing at Boston is initiated. An aircraft, or more properly the nose landing gear component in question, which has been experienced to thousands of flights before towing is required at Boston would have a different life limit than a new part which will experience Boston towing from the beginning. For this reason the analysis of each part is accomplished considering it new, with 8,000 flights, with 24,000 flights and with 40,000 flights. This applies for all three DC-9 models with the exception of the Series 50 which is considered to a maximum of 20,000 flights since the high time Series 50 is on the order of 18,000 flights. This analysis provides a curve of life limit versus the number of flights on the given part at the time the additional towing is initiated at Boston. Along with this, the number of cycles applied can be adjusted to account for the percentage of time a particular aircraft, that is part, operates at Boston. These curves provide the life limits for the particular part in question considering the aircraft on which it is installed as operating every other flight out of

Boston (1/2 time), every third flight (1/3 time), every fourth flight (1/4 time) and every fifth flight (1/5 time). Therefore the final curve for any given part consists of a family of curves representing the Boston operation percentage. The life limit of a part can be determined by knowing the number of flights already accumulated by the part when towing at Boston is initiated and the percent of total operations at Boston. A curve is also provided which indicates the life limit parts would have if the Boston towing spectrum were instituted at all airports served by the aircraft.

If one-way towing were instituted then the life limits for any particular part would merely shift. The curves provided consider towing inbound and outbound. If towing were instituted in one direction only the full time curve would shift to the 1/2 time curve and the 1/2 time curve would shift to the 1/4 time curve. A brief description of each part considered and the analysis performed follows:

1. <u>LOWER DRAG BRACE</u>

The lower drag brace is made of HY-TUF steel heat treated on ultimate tensile strength of 220,000 to 240,000 PSI and 100% shot peened. The lower drag brace transmits the load from the housing assembly to the upper drag braces. This part is loaded primarily by drag loads at the ground or axle. The attach point at the housing assembly consists of a bolt through the single lug of the lower drag brace. The upper end of the lower drag brace consists of a clevis end (double lugs) which is attached to the upper drag braces by means of a bolt. The lugs at either end of the lower drag brace are the fatigue critical areas. Figure 11 indicates the areas of interest.

<u>DC-9 SERIES 10 P/N 5912733</u>

Section A-A was found to be the more critical section for the DC-9 Series 10. Existing analyses in which a comparative analysis was used produced a factor which was unrealisticly high. Considering a factor of three on the calculated fatigue stress produced a life limit which did not obtain a life limit of 40000 flights for an aircraft with 40000 flights already accumulated. A K_F was then determined which produced a life limit of 40000 flights for an aircraft with 40000 flights already accumulated. The K_F was determined to be 2.52. This factor was then used to calculate the life limits for the DC-9

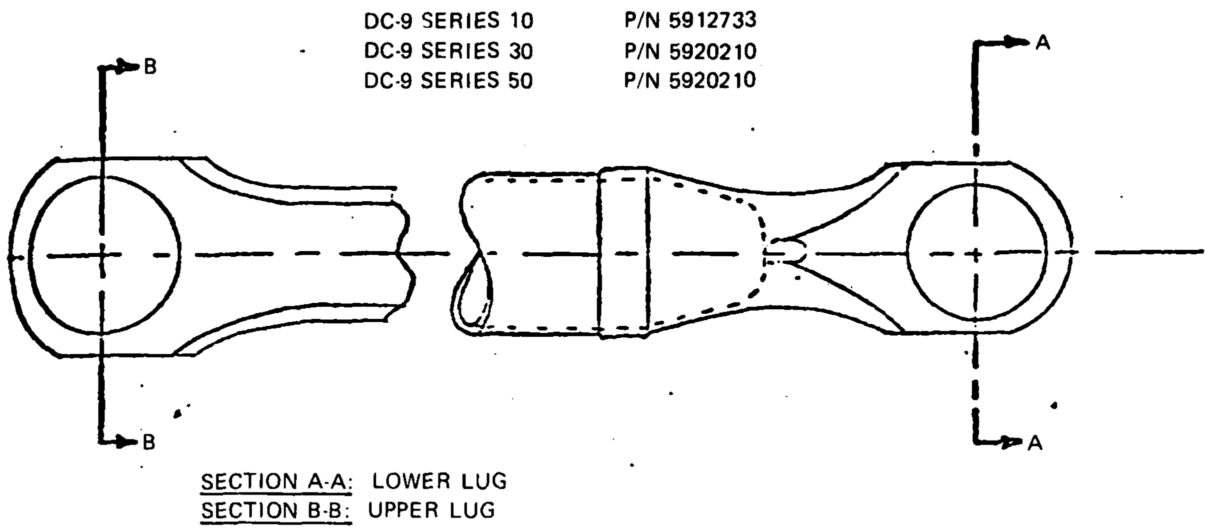


FIGURE 11. LOWER DRAG BRACE

Series 10 lower drag brace as indicated in Figure 12 incorporating a scatter factor of three.

DC-9 SERIES 30 P/N 5920210

The lower drag brace for the Series 30 was strengthened over that for the Series 10 at Section A-A. The analysis indicates that Section B-B is now the critical fatigue area for the Series 30 (Ref. Figure 11). Since the part has been strengthened at Section A-A a $K_F = 3.0$ was applied to Section B-B and the life limits calculated as shown in Figure 13 with no scatter factor applied.

DC-9 SERIES 50 P/N 5920210

This part is the same as used on the Series 30. A $K_F = 3.0$ was used but a life limit of 8000 flights for an aircraft having already accumulated 8000 flights could not be obtained. The upper lugs (Section B-B) for this part are slightly smaller than the similar Series 10 part due to the larger bolt used in the assembly. The K_F determined for the Series 10 was used by modifying it by taking into account the differences in the lug areas. The K_F for the Series 50 was then determined to be 2.6. This K_F was then used to calculate the life limits shown in Figure 14 incorporating a scatter factor of three.

2. UPPER DRAG BRACES

The upper drag braces are made from HY-TUF steel heat treated to an ultimate tensile strength of 220000 to 240000 PSI and 100% shot peened. There are two upper drag braces as indicated in Figure 7. The load from the lower drag brace is transmitted to the fuselage by means of the two upper drag braces. The lower end of the upper drag brace has a single lug while the upper end has a lug-socket arrangement.

DC-9 SERIES 10 P/N 5912595

Analysis indicates that Section C-C at the upper lug-socket is the fatigue critical area. The two methods used in the original analysis did not produce a life limit of 40000 flights for an aircraft having already accumulated 40000 flights. This K_F was determined to be 2.35. The life limits were then determined using this K_F and are shown in Figure 16. The scatter factor of

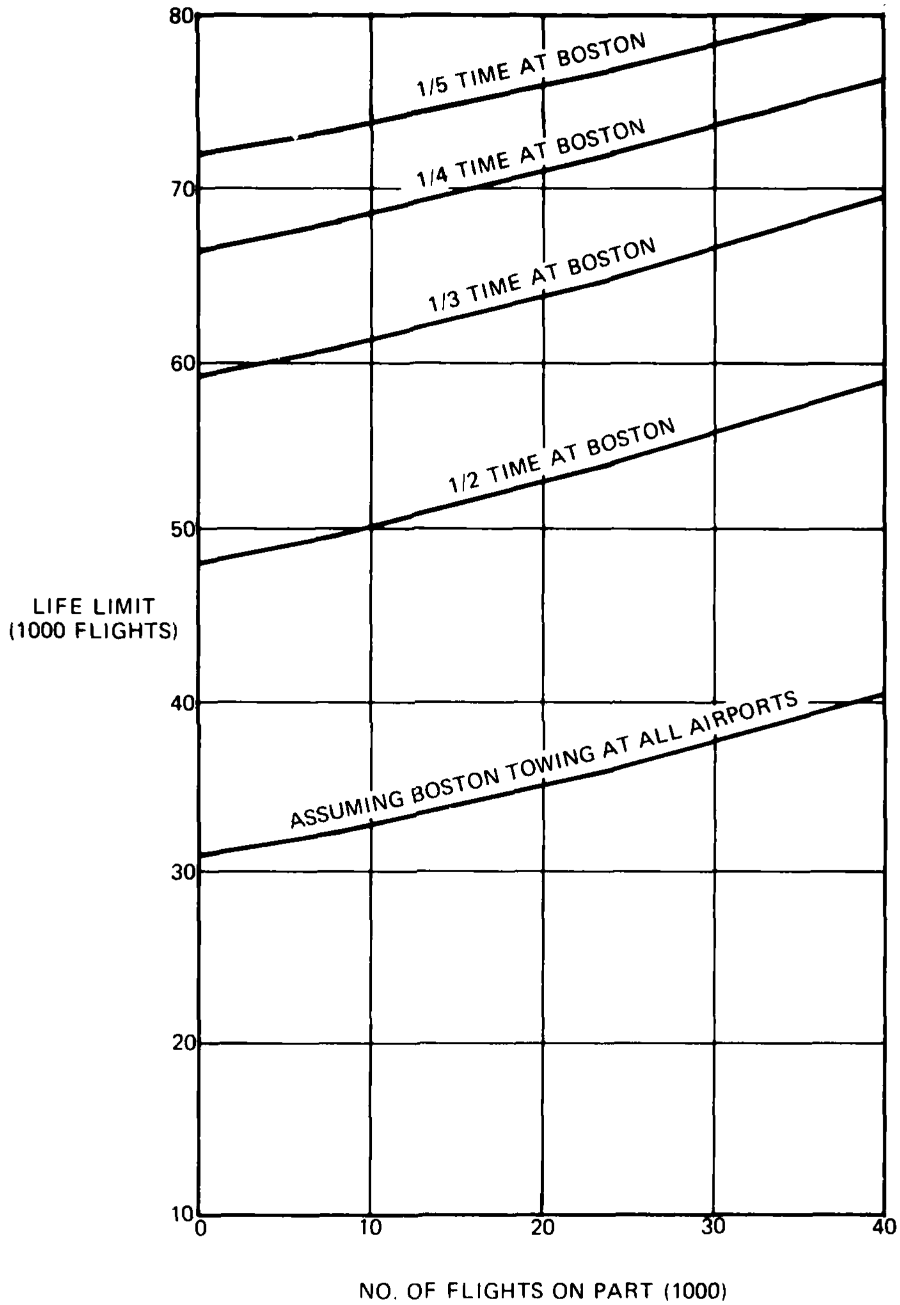


FIGURE 12. DC-9 SERIES 10 PART NO. 5912733, LOWER DRAG BRACE

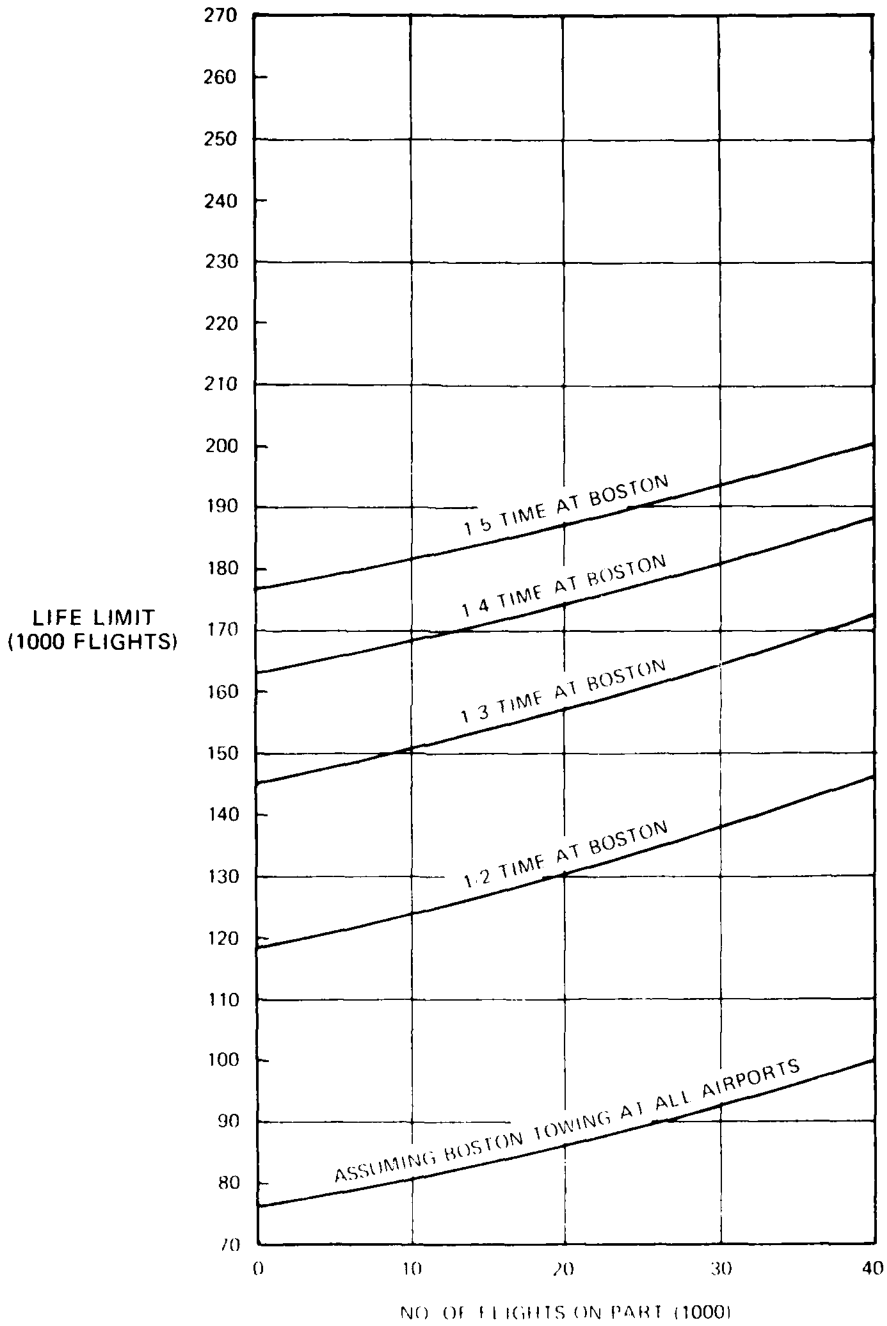


FIGURE 13. DC-9 SERIES 30 PART NO. 5920210, LOWER DRAG BRACE

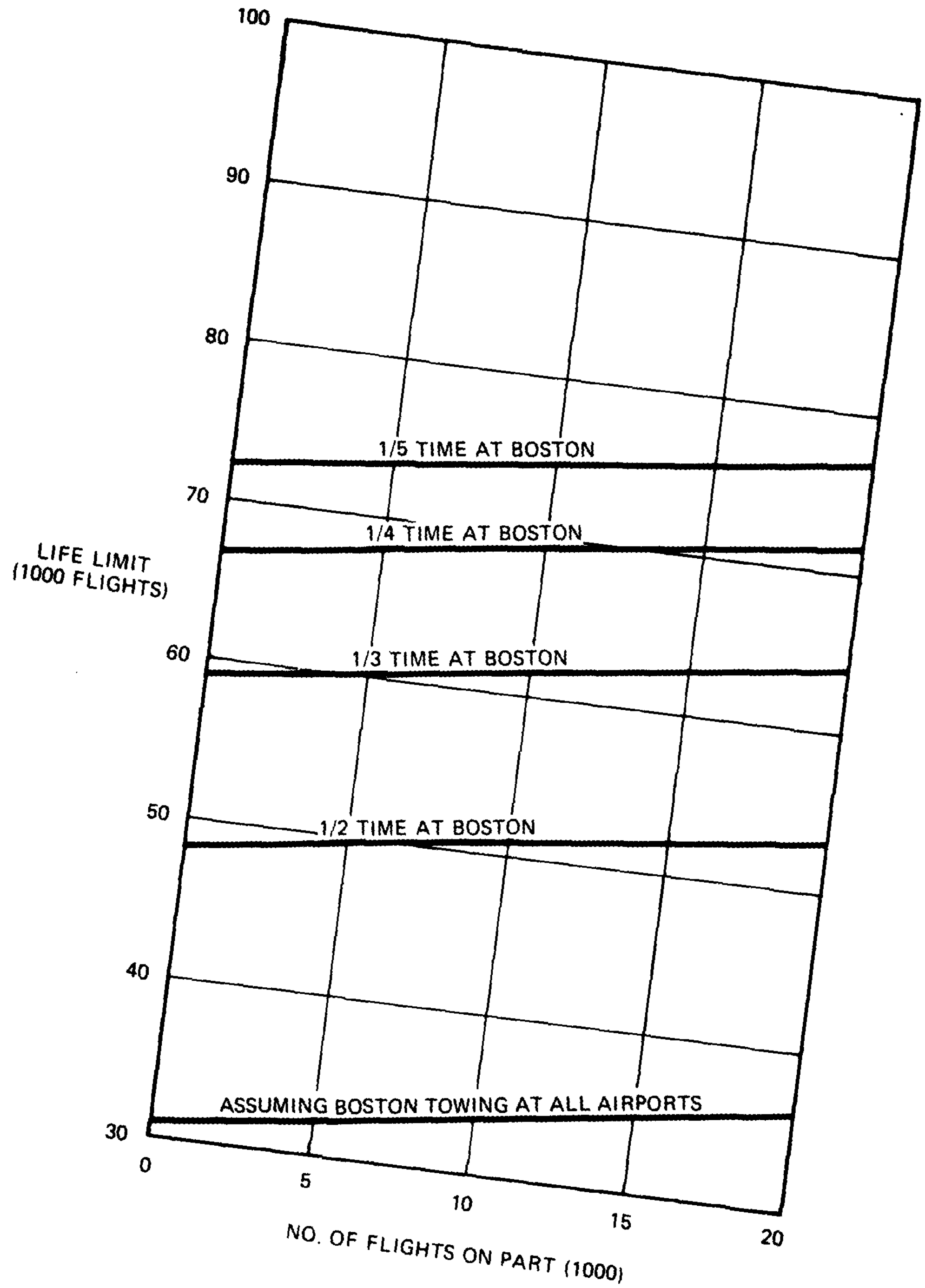
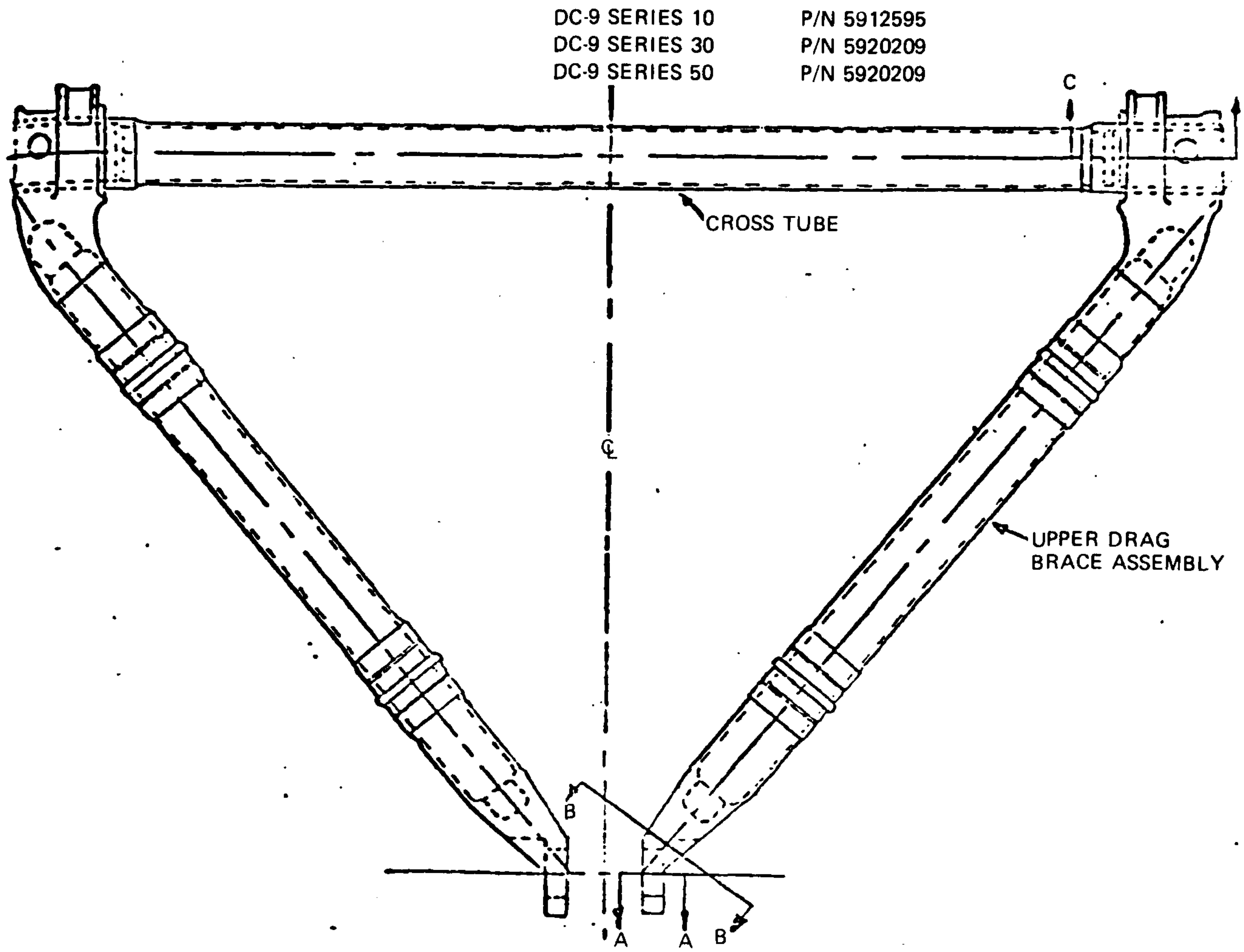


FIGURE 14. DC-9 SERIES 50 PART NO. 5920210, LOWER DRAG BRACE



SECTION A-A: LUG AT ℄ OF KNEE HINGE
SECTION B-B: MINIMUM CROSS SECTION OF BRACE ASSEMBLY
SECTION C-C: LUG SOCKET AT ℄ OF CROSS TUBE

FIGURE 15. UPPER DRAG BRACE

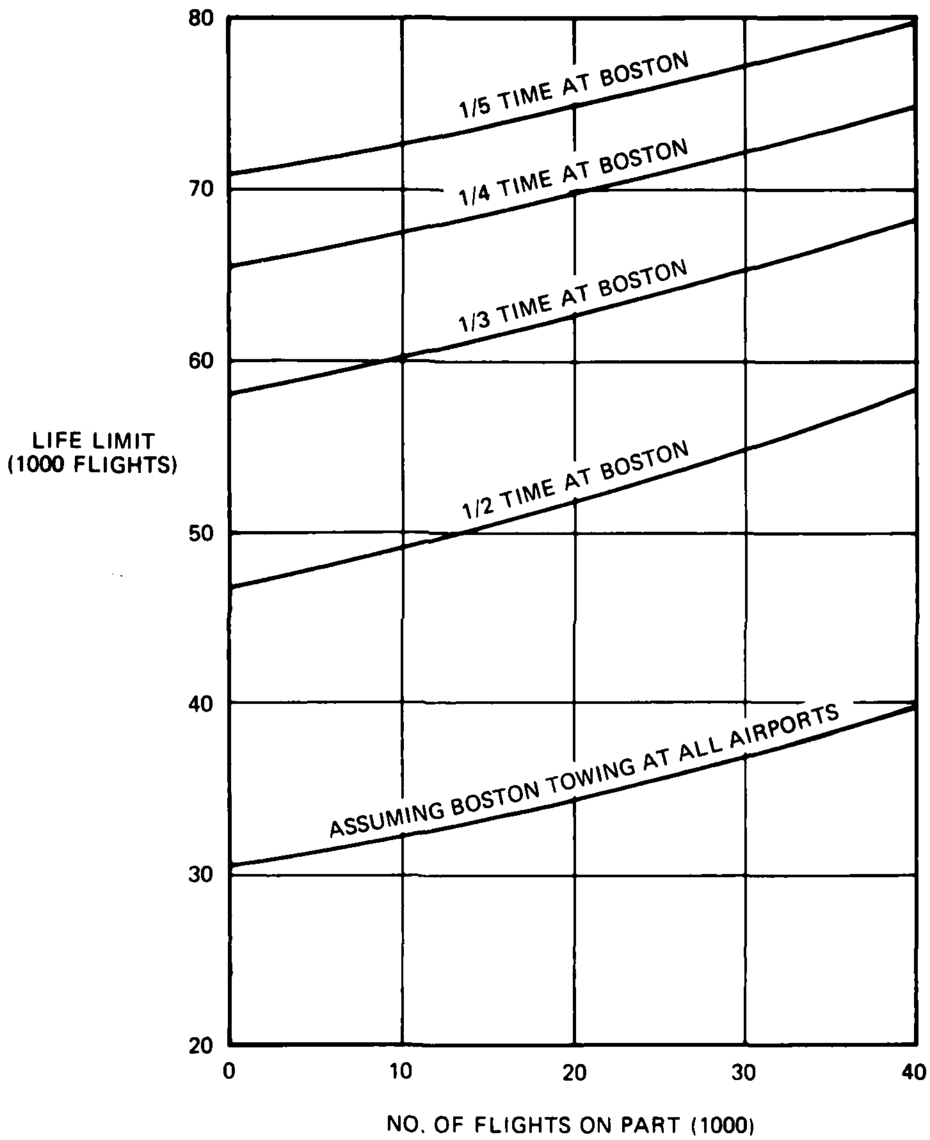


FIGURE 16. DC-9 SERIES 10 PART NO. 5912595, UPPER DRAG BRACE

3 on cycles was reduced to 2.58 for two specimens as in the original analysis.

DC-9 SERIES 30 P/N 5920209

The analysis indicates that Section C-C at the upper lug-socket is the fatigue critical area. Neither the two methods used in the original analysis nor the K_F determined for the Series 10 upper drag brace produced a life limit of 32000 flights for an aircraft which had already accumulated 32000 flights. Therefore a K_F was determined which would produce the required 32000 flights. This K_F was calculated to be 2.11. The life limits were then determined using this K_F as shown in Figure 17, incorporating a scatter factor of three.

DC-9 SERIES 50 P/N 5920209

The analysis indicates that Section C-C at the upper lug-socket is the fatigue critical area. Neither the two methods used in the original analysis nor the K_F determined for the Series 30 upper drag brace produced a life limit of 8000 flights for an aircraft which had already accumulated 8000 flights. Therefore a K_F was determined which would produce the required 8000 flights. This K_F was calculated to be 2.08. The life limits were then determined using this K_F as shown in Figure 18, incorporating a scatter factor of three.

3. PIN-END CROSS-TUBE

The Pin-end is the means of attachment of the upper side brace and the cross tube to the fuselage as shown in Figure 19. The pin is manufactured from 4340 steel and heat treated to an ultimate tensile strength of 180000 to 200000 psi.

DC-9 SERIES 10 P/N 4912593

Section A-A as shown in Figure 19 was determined to be the fatigue critical section. Neither of the two methods used in the original analysis would produce a life limit of 40000 flights for an aircraft which had already accumulated 40000 flights. A K_F of 1.05 was then determined which would produce the required 40000 flights. The analysis was then conducted using this K_F and a scatter factor of 2.58 for two specimens and the life limits are shown in Figure 20.

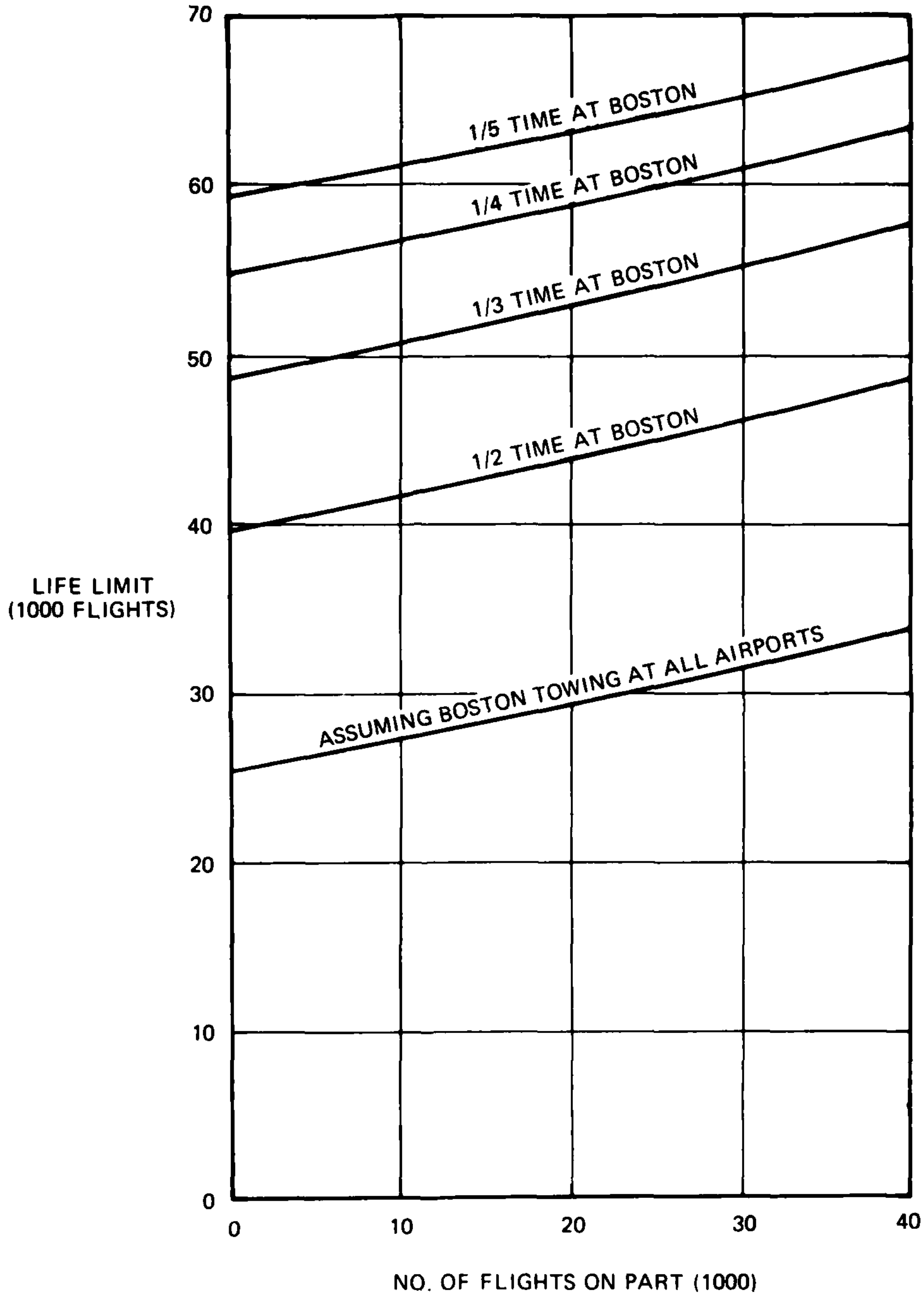


FIGURE 17. DC-9 SERIES 30 PART NO. 5920209, UPPER DRAG BRACE

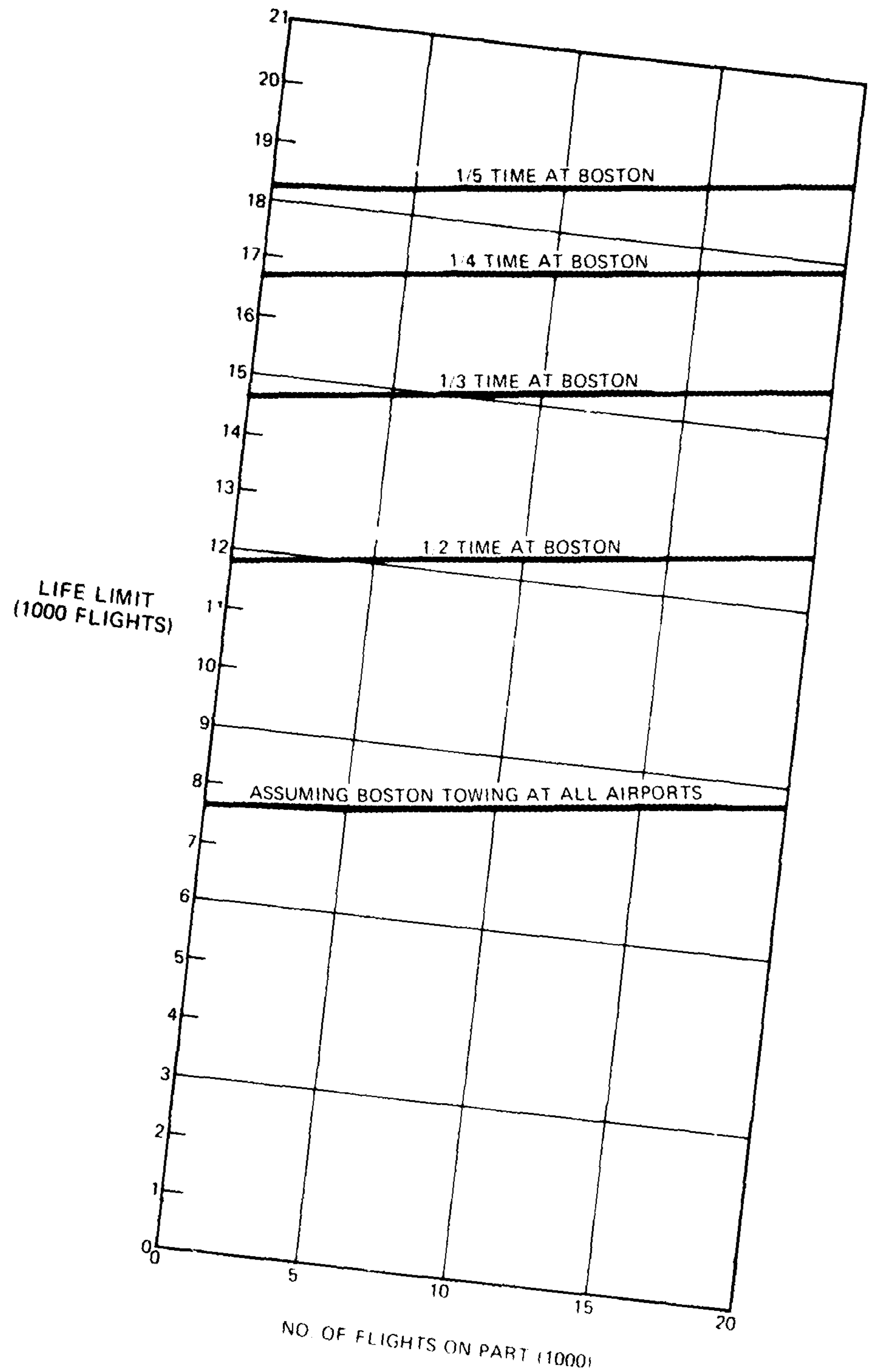
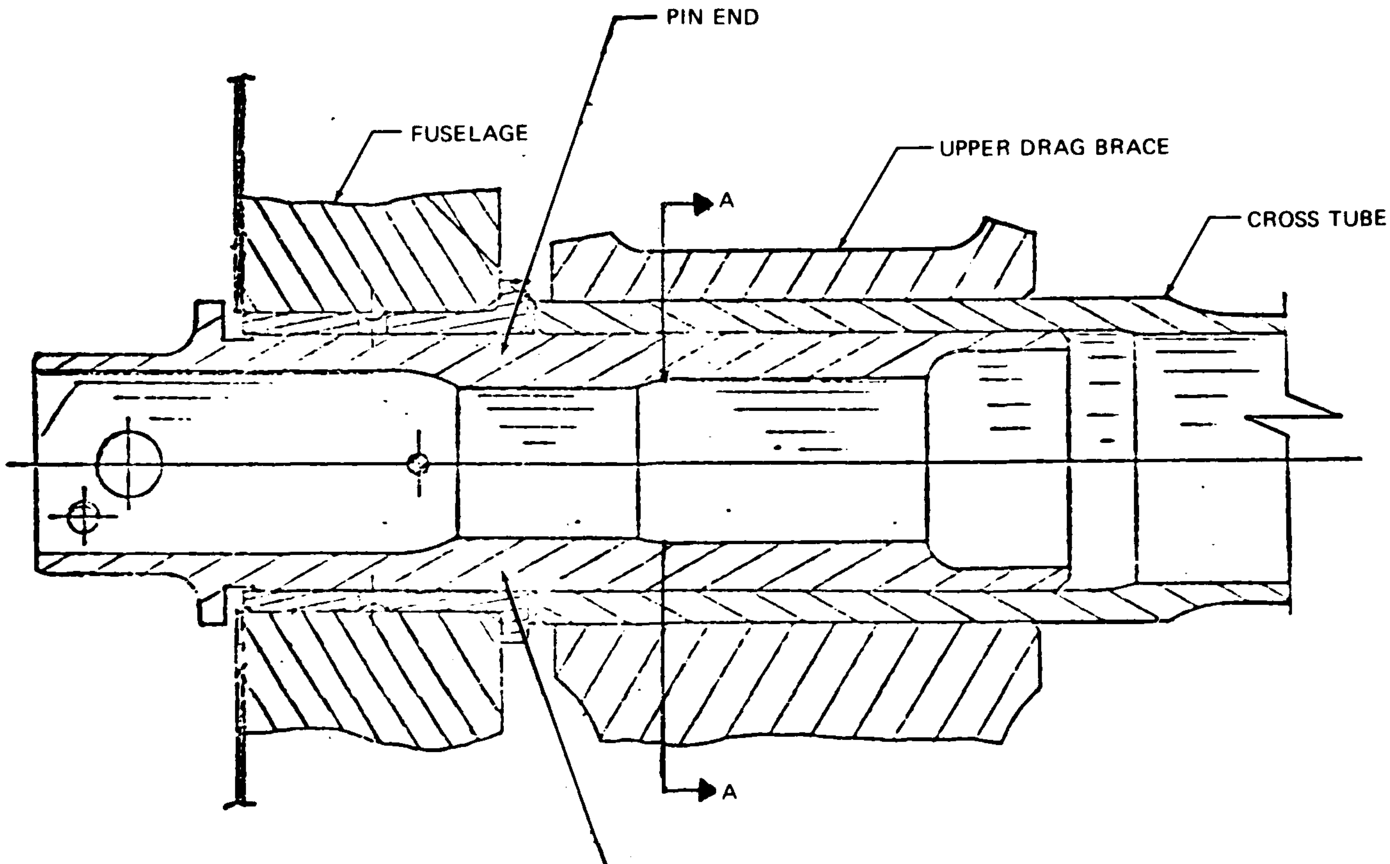


FIGURE 18. DC-9 SERIES 50 PART NO. 5920209, UPPER DRAG BRACE

DC-9 SERIES 10
DC-9 SERIES 30
DC-9 SERIES 50

P/N 4912593



SECTION A-A: POINT OF MAXIMUM STRESS

FIGURE 19. PIN-END CROSS TUBE

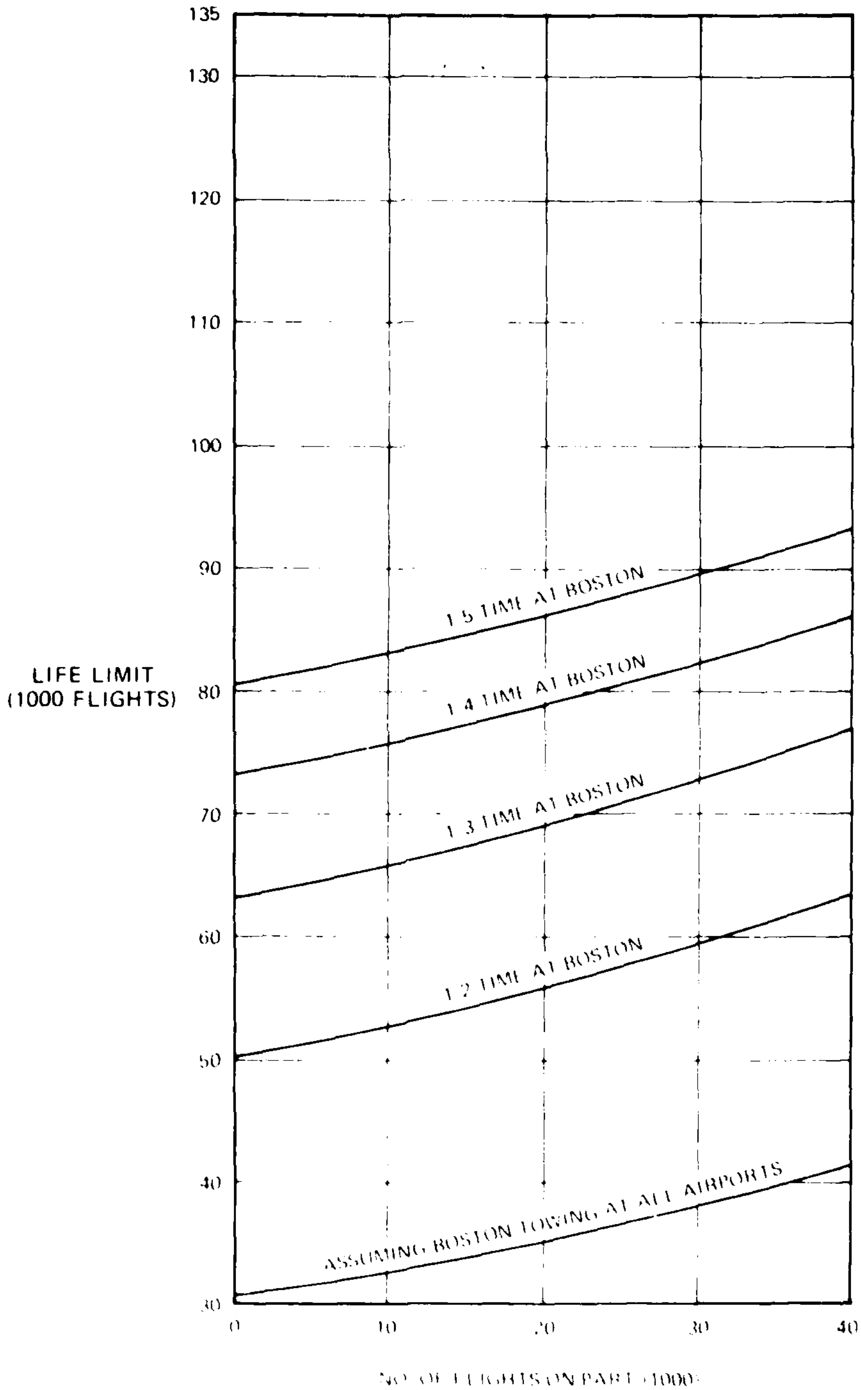


FIGURE 20. DC 9 SERIES 10 PART NO. 4912593, PIN-END, CROSS-TUBE

DC-9 SERIES 30 P/N 4912593

The K_F developed for the Series 10 would not provide the required 32000 flights for an aircraft which has already accumulated 32000 landings. Therefore a K_F was determined for the Series 30 which would produce the required 32000 flights. However this K_F was determined to be less than 1.0. Therefore a K_F of 1.0 was used in the analysis along with a scatter factor of 2.58 for two specimens and the life limits are shown in Figure 21.

DC-9 SERIES 50 P/N 4912593

The K_F of 1.0 used in the Series 30 analysis was used for the Series 50 and the life limit for an aircraft with 8000 accumulated flights exceeded the required 8000 flights. The analysis was conducted using a K_F = 1.0 and a scatter factor of 2.58 for two specimens and the life limits are shown in Figure 22.

4. BOLT-KNEE HINGE

The bolt at the knee hinge provides the means of attachment for the lower and upper drag braces as shown in Figure 23. The Series 10 bolt was originally manufactured from 4340 steel heat treated to an ultimate tensile strength of 180000 to 200000 psi. A subsequent revision (-501) changed the material to HY-TUF steel heat treated to 220000 to 240000 psi. The Series 30 and 50 bolts are of a larger diameter and have a different part number than the Series 10.

DC-9 SERIES 10 P/N 4912734-1

The two methods of determining life limits in the original analysis did not provide the required 40000 flights for a Series 10 aircraft which had already accumulated 40000 flights. The K_F required to meet this criteria was less than 1.0, therefore K_F = 1.0 was used in the analysis along with a scatter factor of three. The life limits obtained are indicated in Figure 24.

DC-9 SERIES 10 P/N 4912734-501

As previously explained, this part was modified using HY-TUF steel. A K_F of 1.0 was determined for this part also and using a scatter factor of three the life limits are indicated in Figure 25. The -1 part has been discontinued and all subsequent parts are of the -501 (HY-TUF) configuration.

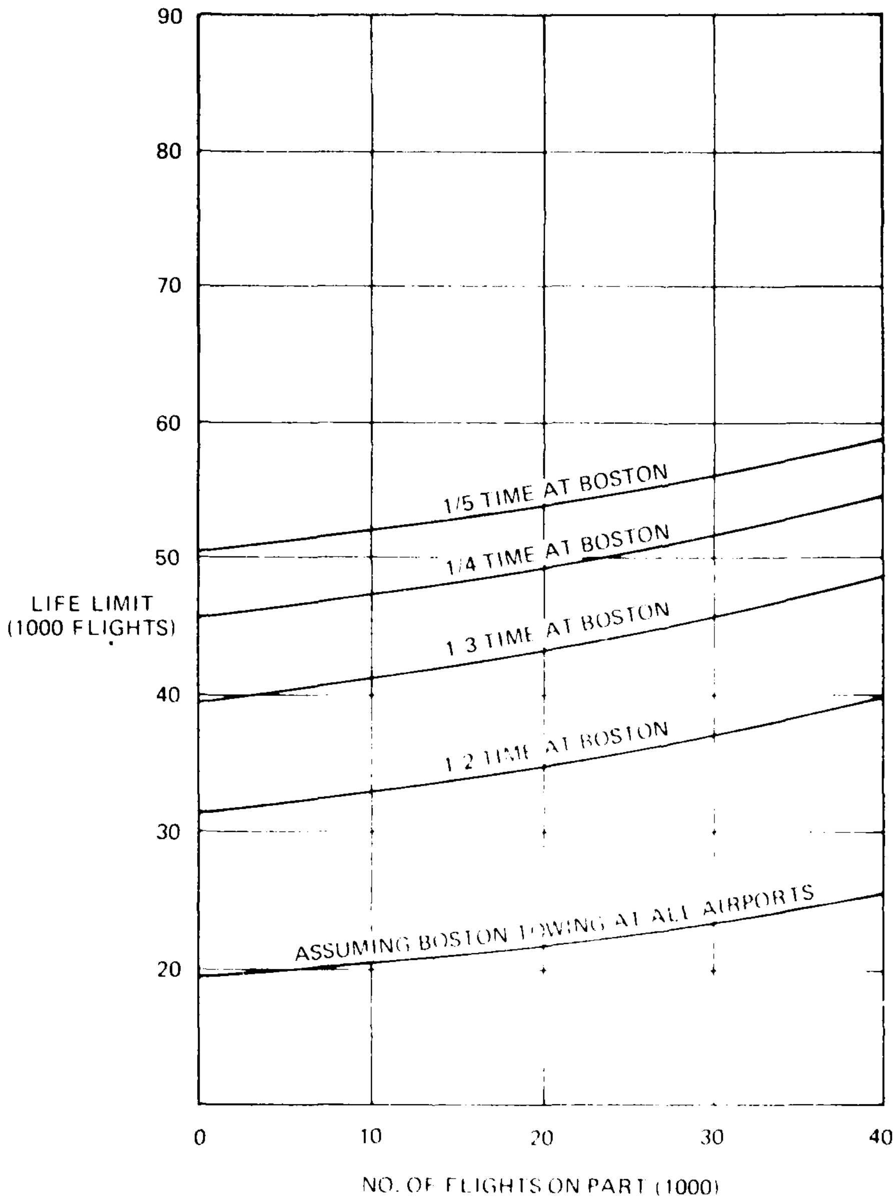


FIGURE 21. DC-9 SERIES 30 PART NO. 4912593, PIN-END, CROSS-TUBE

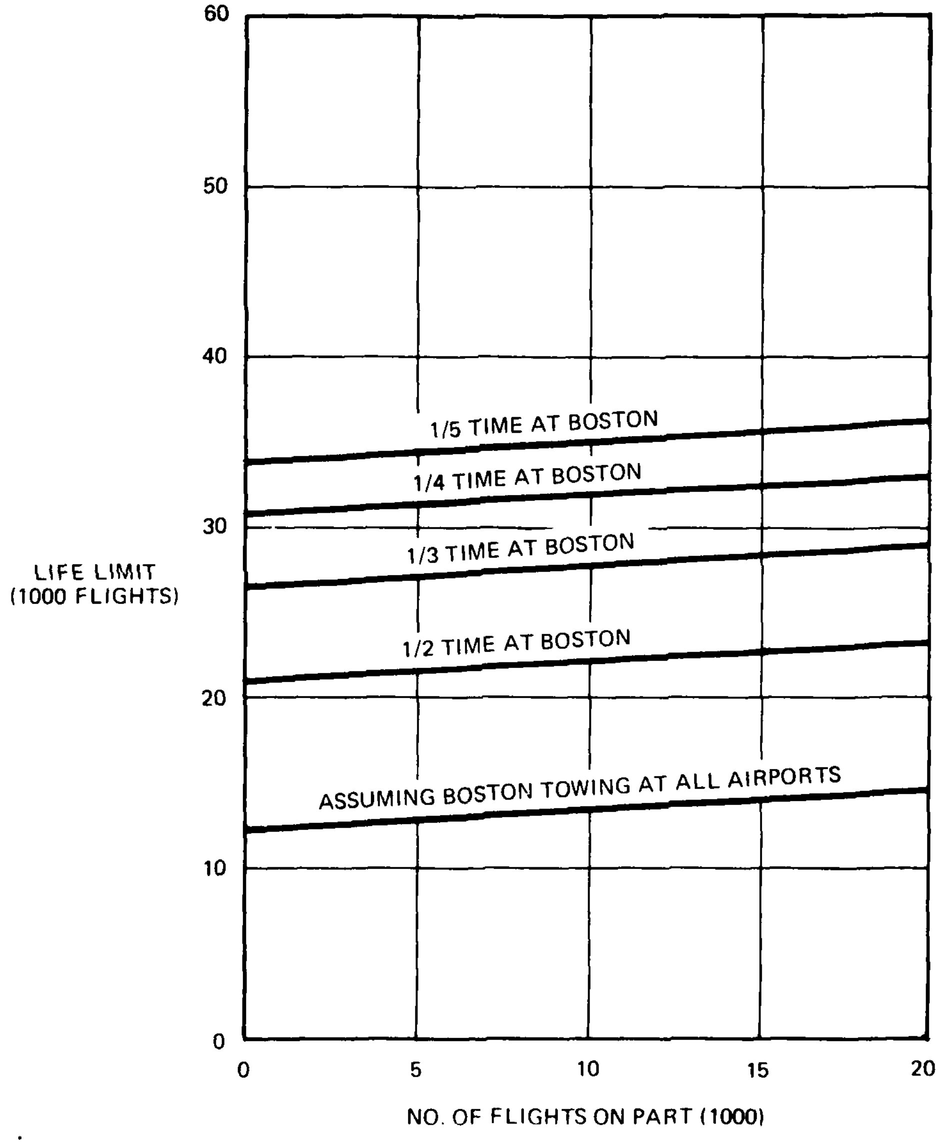


FIGURE 22. DC-9 SERIES 50 PART NO. 4912593, PIN-END, CROSS-TUBE

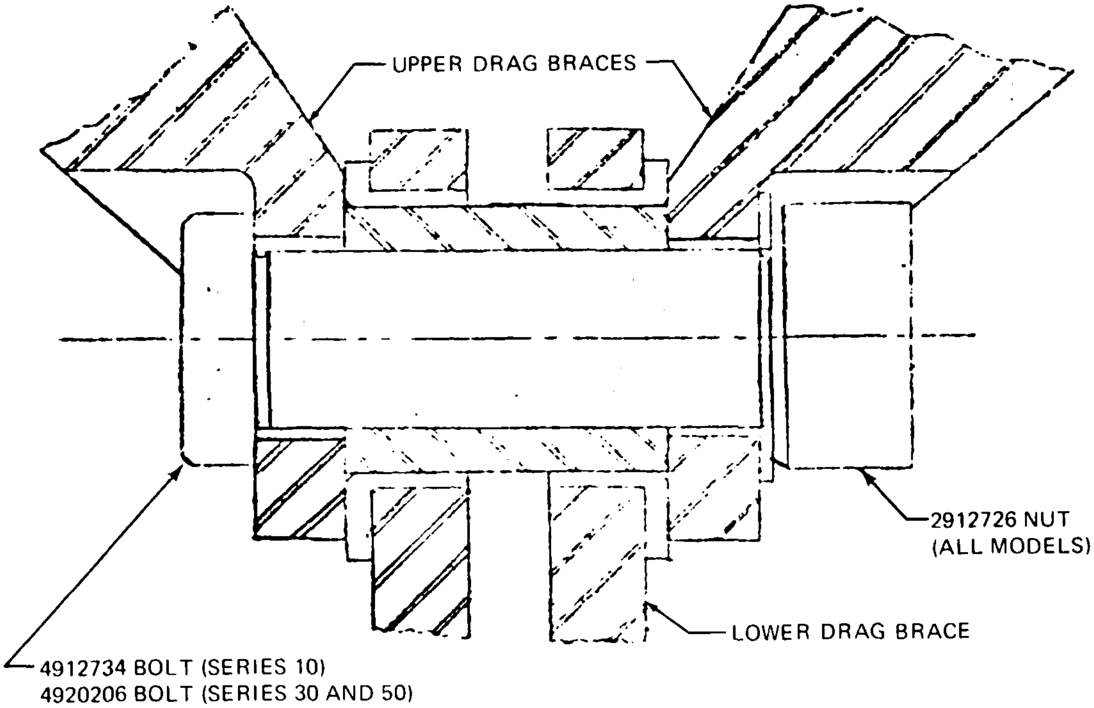


FIGURE 23. KNEE HINGE

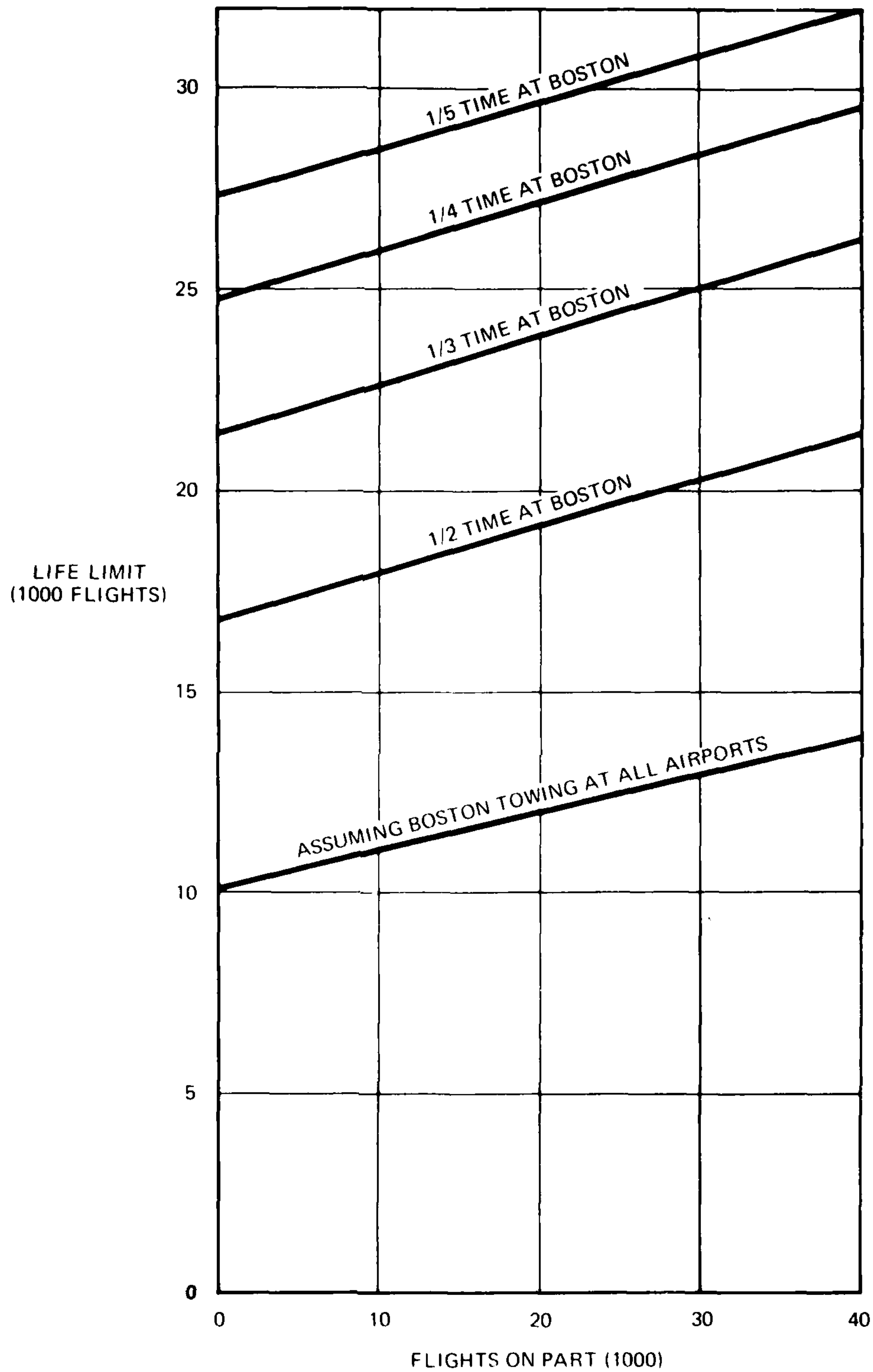


FIGURE 24. DC-9 SERIES 10 PART NO. 4912734-1, BOLT-KNEE HINGE

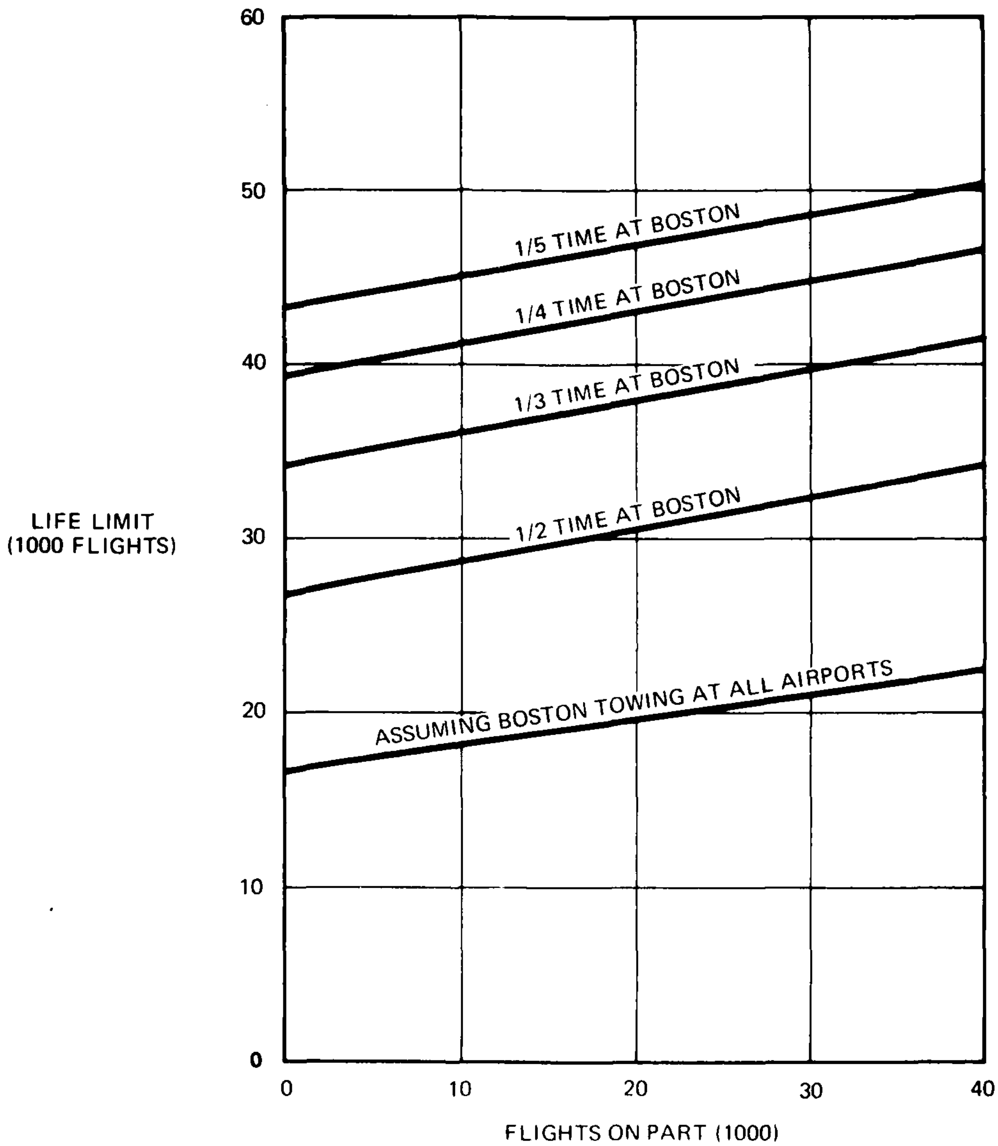


FIGURE 25. DC-9 SERIES 10 PART NO. 4912734-501, BOLT-KNEE HINGE

DC-9 SERIES 30 P/N 4920206

The two methods of determining life limits in the original analysis did not provide the required 32000 flights for a Series 30 aircraft which had already accumulated 32000 flights. The K_F required to meet this criteria was less than 1.0, therefore $K_F = 1.0$ was used in the analysis along with a scatter factor of three. The life limits obtained are indicated in Figure 26.

DC-9 SERIES 50 P/N 4920206

The two methods of determining life limits in the original analysis did not provide the required 8000 flights for a Series 50 aircraft which had already accumulated 8000 flights. Therefore the $K_F = 1.0$ used in the Series 30 analysis was used for the Series 50 along with a scatter factor of three. The life limits obtained are indicated in Figure 27.

5. NUT-KNEE HINGE

The nut used in conjunction with the bolt in the knee hinge is loaded by induced axial loads in the bolt due to the angle of the attaching parts. The nut is indicated in Figure 23. The analysis was conducted using a factor of three on the calculated fatigue stress ($K_F = 3.0$) and life limits in excess of 200000 flights were realized for all DC-9 models.

6. BOLT-SHOULDER-DRAG BRACE

This bolt is the means of attachment of the lower drag brace to the housing assembly as shown in Figure 28. The bolt is manufactured from HY-TUF steel heat treated to an ultimate tensile strength of 220000 to 240000 psi.

DC-9 SERIES 10 P/N 3958414

Neither of the two methods of determining life limits used in the original analysis provided the required 40000 flights for a Series 10 aircraft which had already accumulated 40000 flights. A K_F of 1.3 was required to produce the needed 40000 flights. This K_F along with a scatter factor of three was used to arrive at the life limits shown in Figure 29.

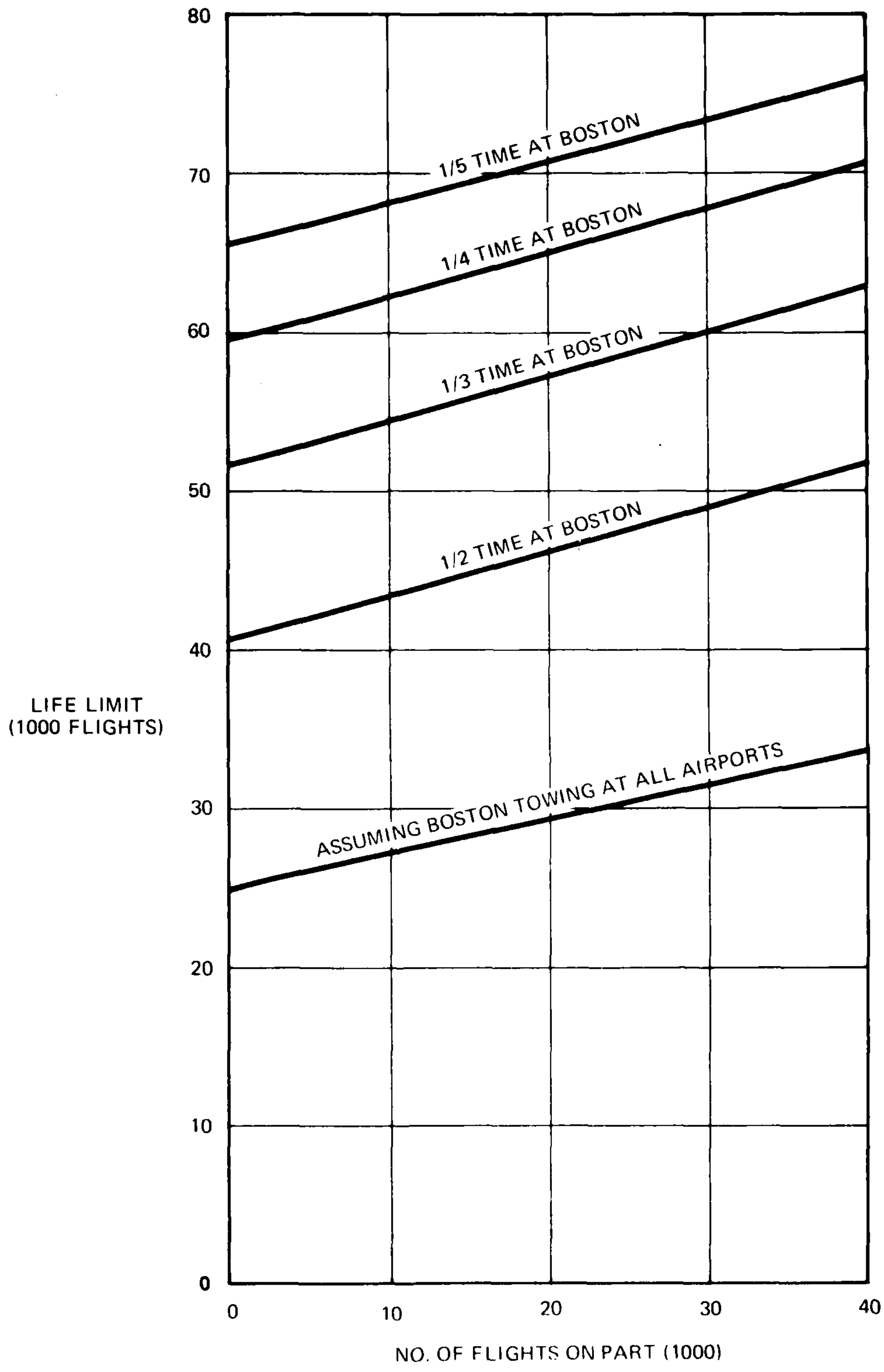


FIGURE 26. DC-9 SERIES 30 PART NO. 4920206, BOLT-KNEE HINGE

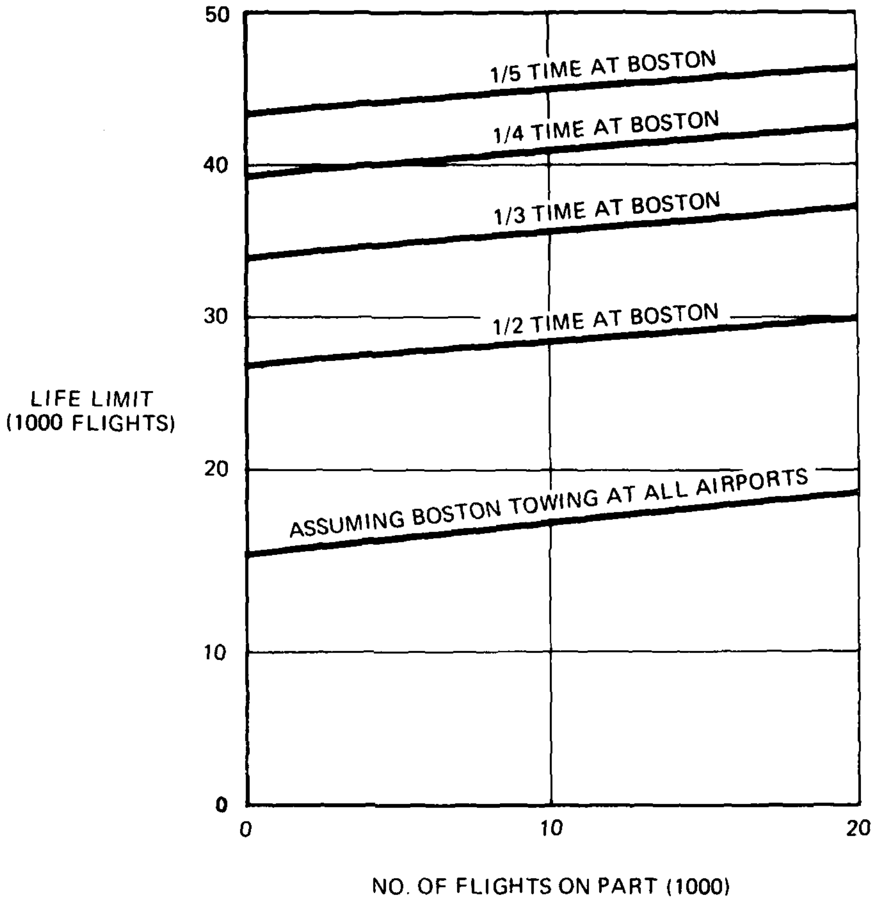


FIGURE 27. DC-9 SERIES 50 PART NO. 4920206, BOLT-KNEE HINGE

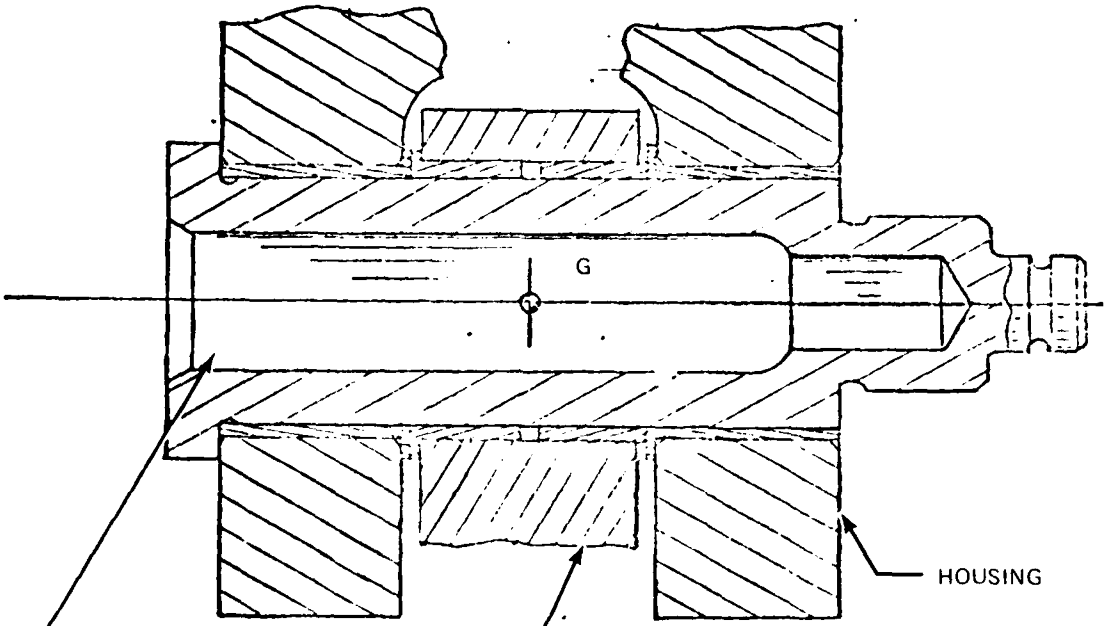


FIGURE 28. BOLT, SHOULDER-DRAG BRACE

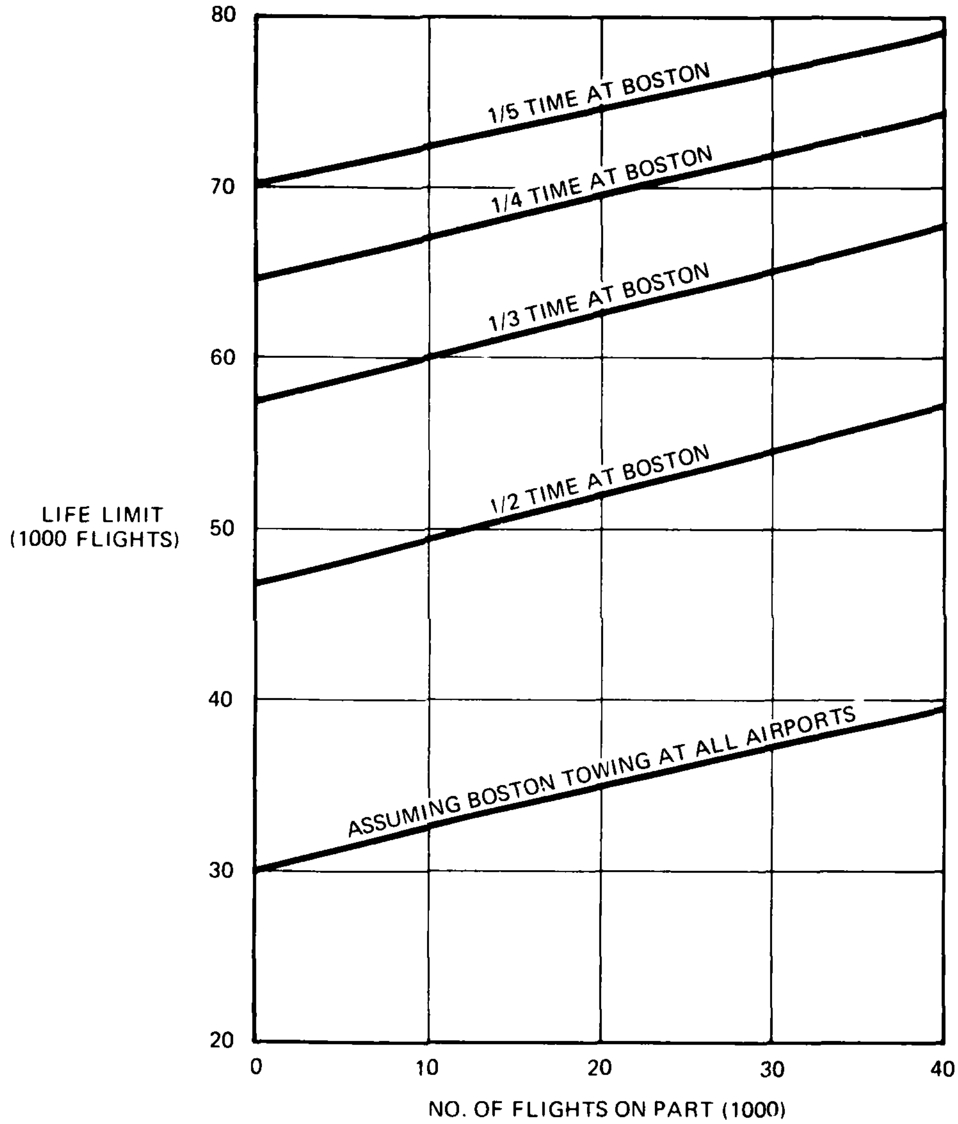


FIGURE 29. DC-9 SERIES 10 PART NO. 3958414, BOLT, SHOULDER-DRAG BRACE

DC-9 SERIES 30 P/N 3920626

This bolt is similar to the Series 10 bolt with the inside diameter reduced to provide additional strength. Neither of the two methods of determining life limits used in the original analysis provided the required 32000 flights for a Series 30 aircraft which had already accumulated 32000 flights. A K_F of 1.63 was required to produce the needed 32000 flights. This K_F along with a scatter factor of three was used to arrive at the life limits shown in Figure 30.

DC-9 SERIES 50 P/N 3920626

This bolt is the same as used on the Series 30 aircraft. The K_F used in the Series 30 analysis provided a life limit greater than 8000 flights for an aircraft which had accumulated 8000 flights. Therefore the same K_F (1.63) was used in the Series 50 analysis and the life limits are indicated in Figure 31.

7. HOUSING

The housing is the main load carrying structure of the nose landing gear. The area of concern in this analysis is the drag brace attach point as indicated in Figure 32. The housing is manufactured from 7075-T73 aluminum forging.

DC-9 SERIES 10 P/N 5927071 AND 5928678

The two parts which are currently in use for the Series 10 are identical in the area of the drag brace attach and will be analyzed together. A K_F of three was used in this analysis without a scatter factor and adequate life in excess of the required 40000 flights for a Series 10 aircraft which had already accumulated 40000 flights was obtained. The life limits calculated are shown in Figure 33. These life limits are for the brace attach area only and any life limit already established for these parts which is less than those indicated in Figure 33 will take precedence.

DC-9 SERIES 30 P/N 5927079 AND 5920601

These two parts which are currently in use for the Series 30 are identical in the area of the drag brace attach and will be analyzed together. A K_F of three was used in this analysis without a scatter factor and life limits in excess

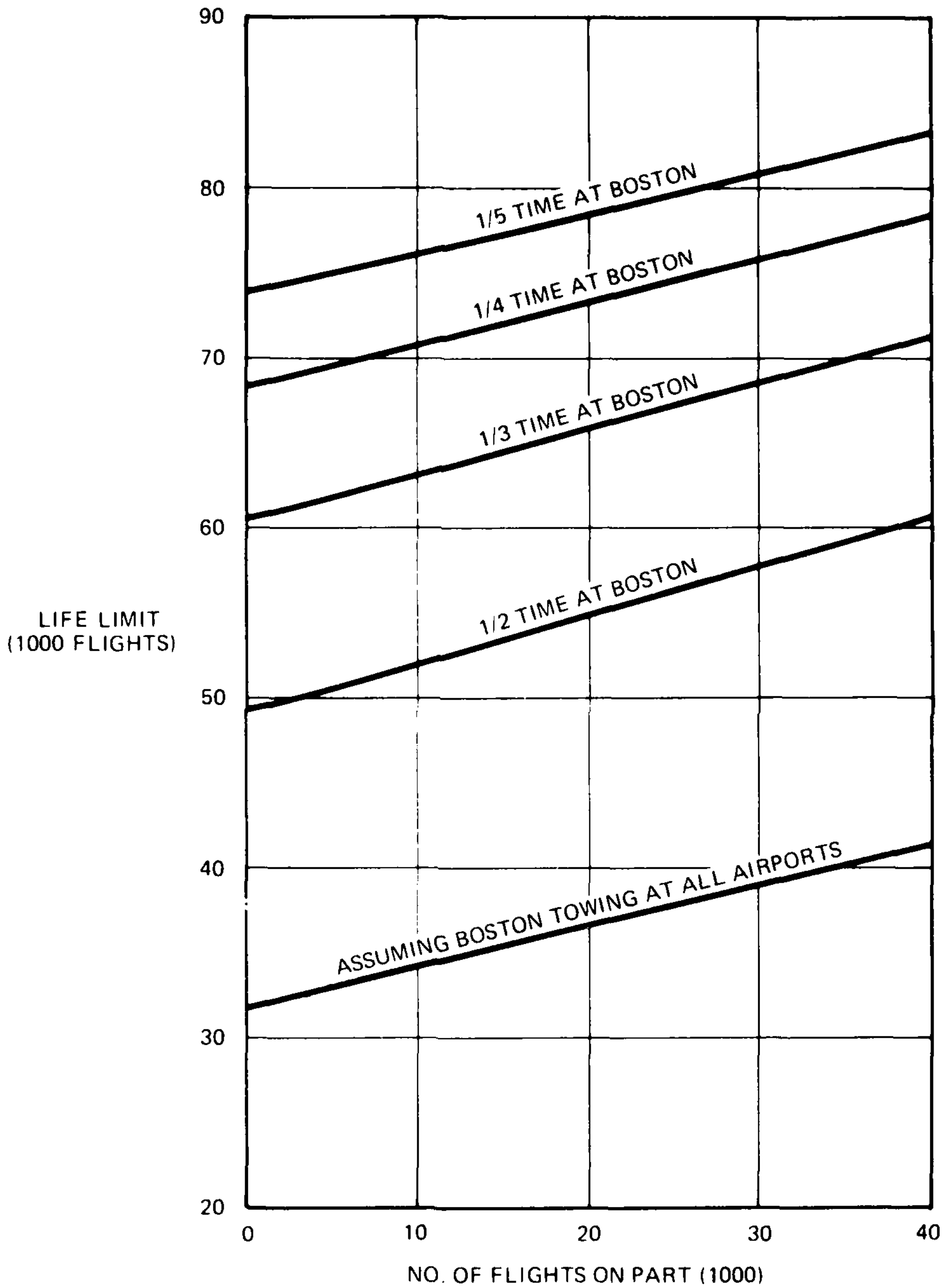


FIGURE 30. DC-9 SERIES 30 PART NO. 3920626, BOLT, SHOULDER-DRAG BRACE

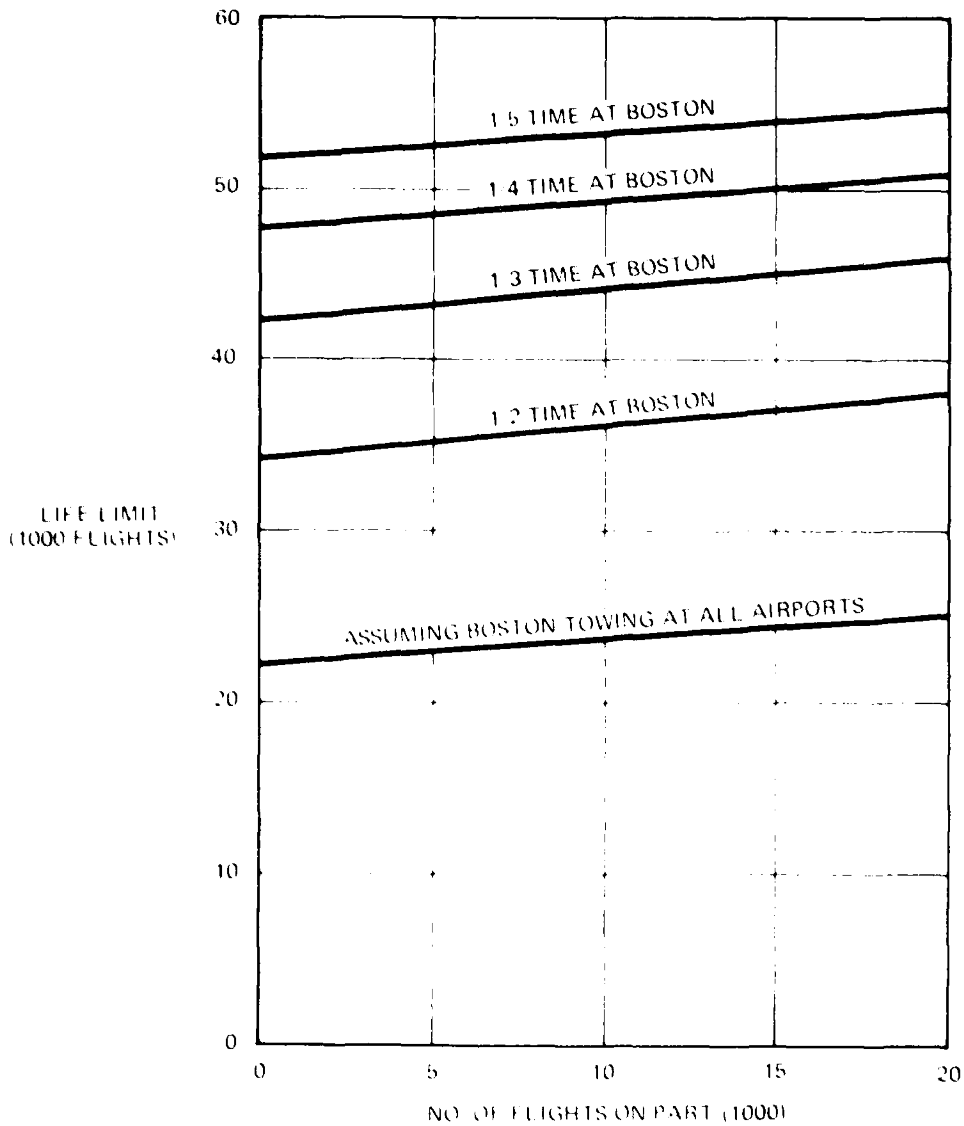


FIGURE 31. DC 9 SERIES 50 PART NO. 3920626, BOLT, SHOULDER DRAG BRACE

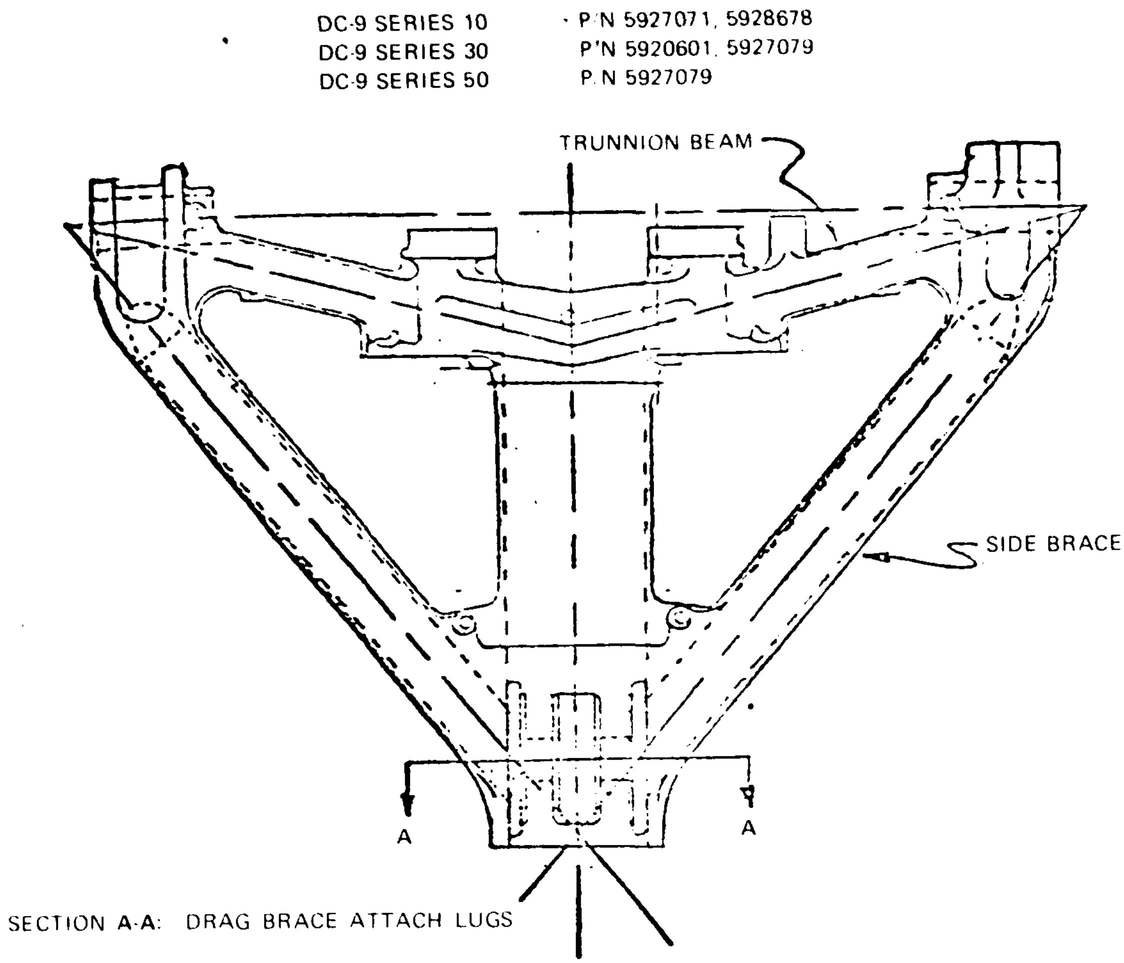


FIGURE 32. HOUSING

of the required 32000 flights for a Series 30 aircraft which had already accumulated 32000 flights was obtained. The life limits calculated are shown in Figure 34. These life limits are for the brace attach area only and any life limit already established for these parts which is less than those indicated in Figure 35 will take precedence.

DC-9 SERIES 50 P/N 5927079

A K_F of three was used in this analysis without a scatter factor and adequate life in excess of the required 8000 flights for a Series 50 aircraft which had already accumulated 8000 flights was obtained. The life limits calculated are shown in Figure 35.

8. PISTON-AXLE ASSEMBLY

Towing is not considered to be a fatigue critical condition for the piston-axle assembly. Conditions producing large vertical loads (landing and braking) and conditions producing large vertical loads in combination with side loads (braked turns) are more damaging to the piston-axle assembly than the proposed Boston towing regime. Airplane braking and braked turns would be less frequent in the Boston towing regime therefore any small additional damage caused by towing would be overcome by the less frequent braking maneuvers. In addition the points of maximum stress on the axle would differ for the towing conditions versus the braking conditions. A combination of vertical and drag loads (towing) would result in a maximum stress in the axle at approximately 45° from the bottom centerline where as a combination of vertical and side loads (braked) turn) would result in a maximum stress in the axle near the bottom centerline. By a similar rational, the piston would be exposed to bending about the side axis for towing and about the drag axis for braked turns. The fatigue damage accumulated under these conditions would not, therefore, be directly additive. The life limits for the piston-axle assembly is not considered affected by the Boston towing operation and existing life limits for these parts would apply.

9. SUPPORT STRUCTURE

The fuselage support structure in the area of the upper drag brace attach is not considered to be a fatigue critical area. The socket has redundant load paths and a crack of any significant size would be readily detectable. A periodic

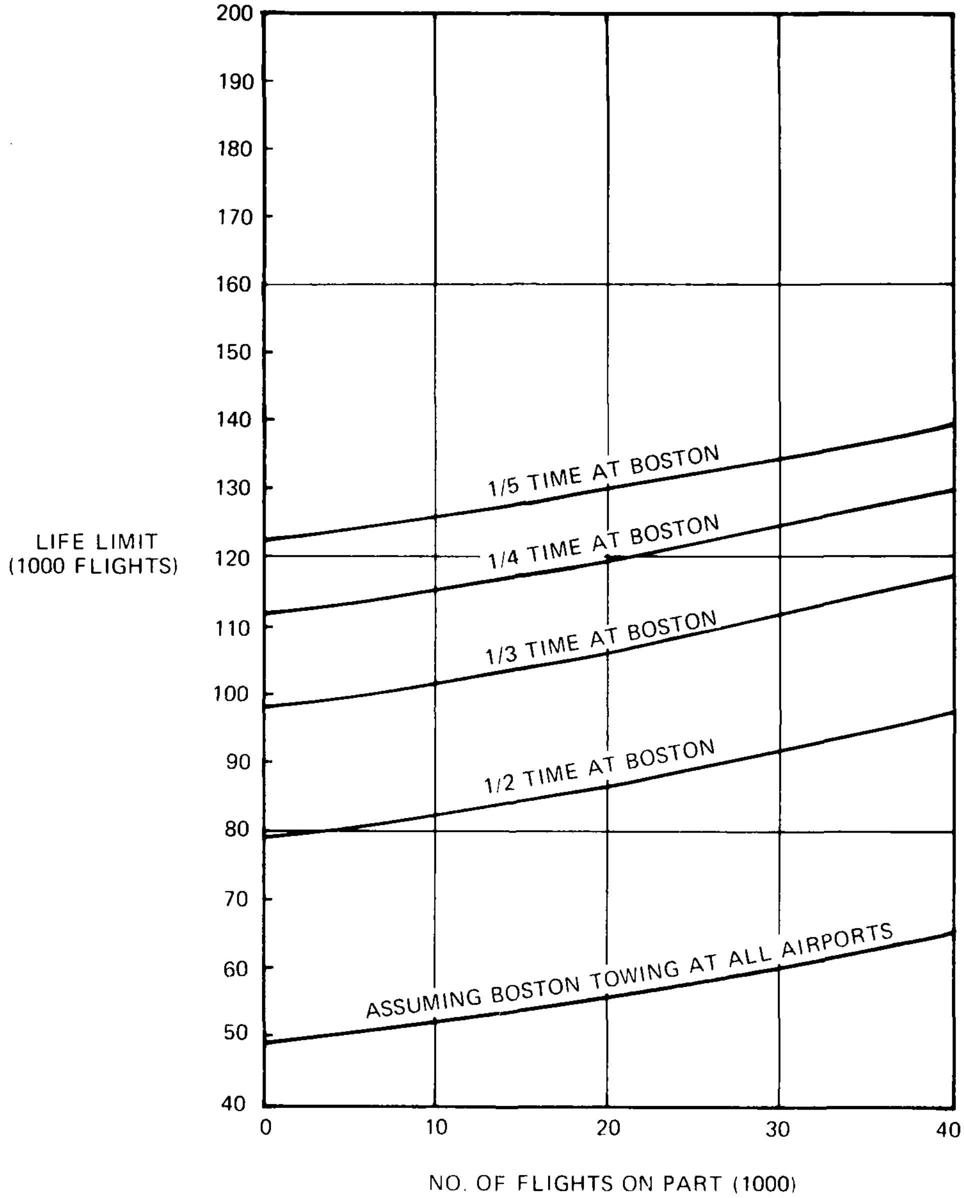


FIGURE 33. DC-9 SERIES 10 PART NO. 5927071 AND PART NO. 5928678, HOUSING

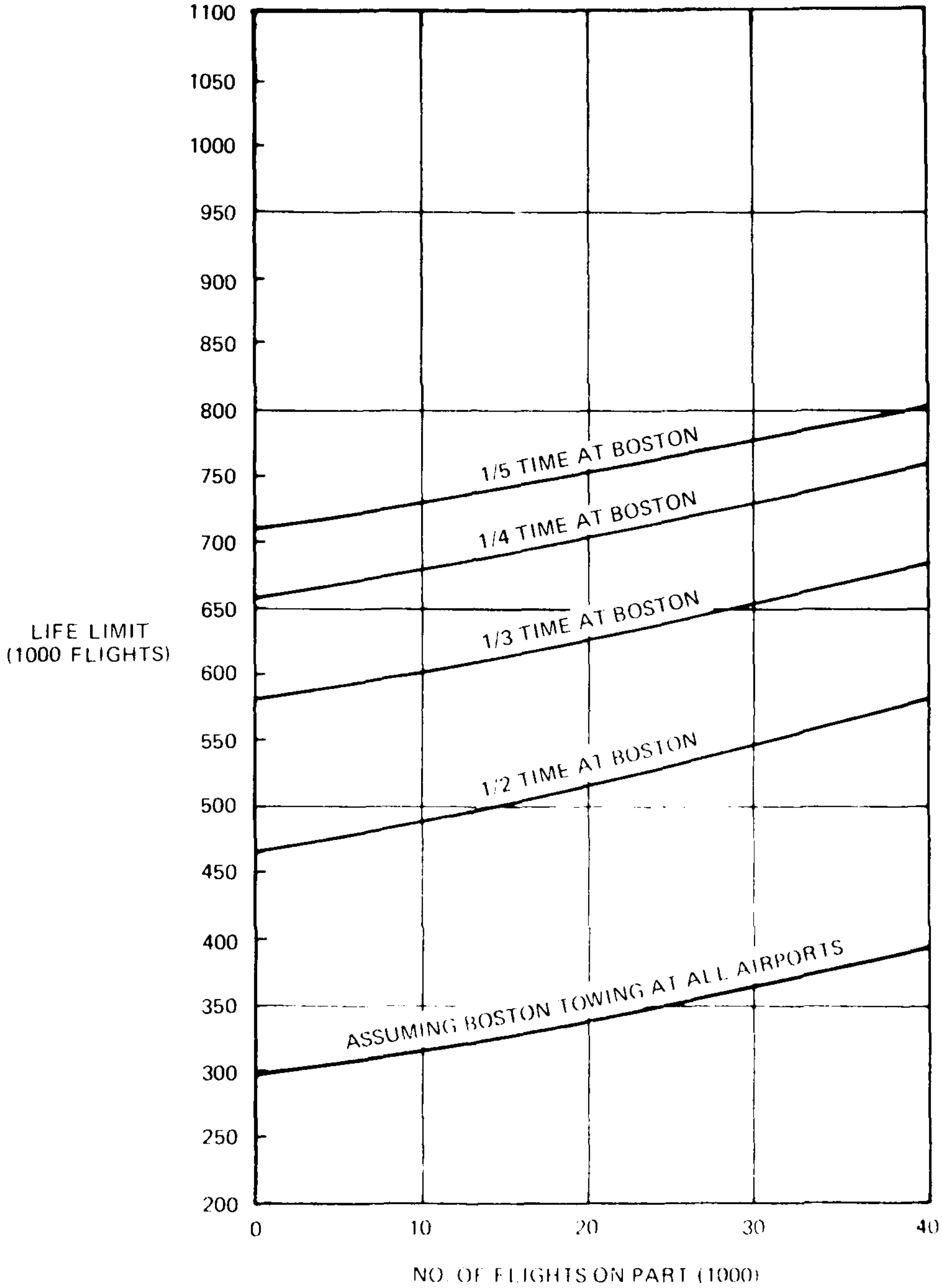


FIGURE 34. DC-9 SERIES 30 PART NO. 5927079 AND PART NO. 5920601, HOUSING

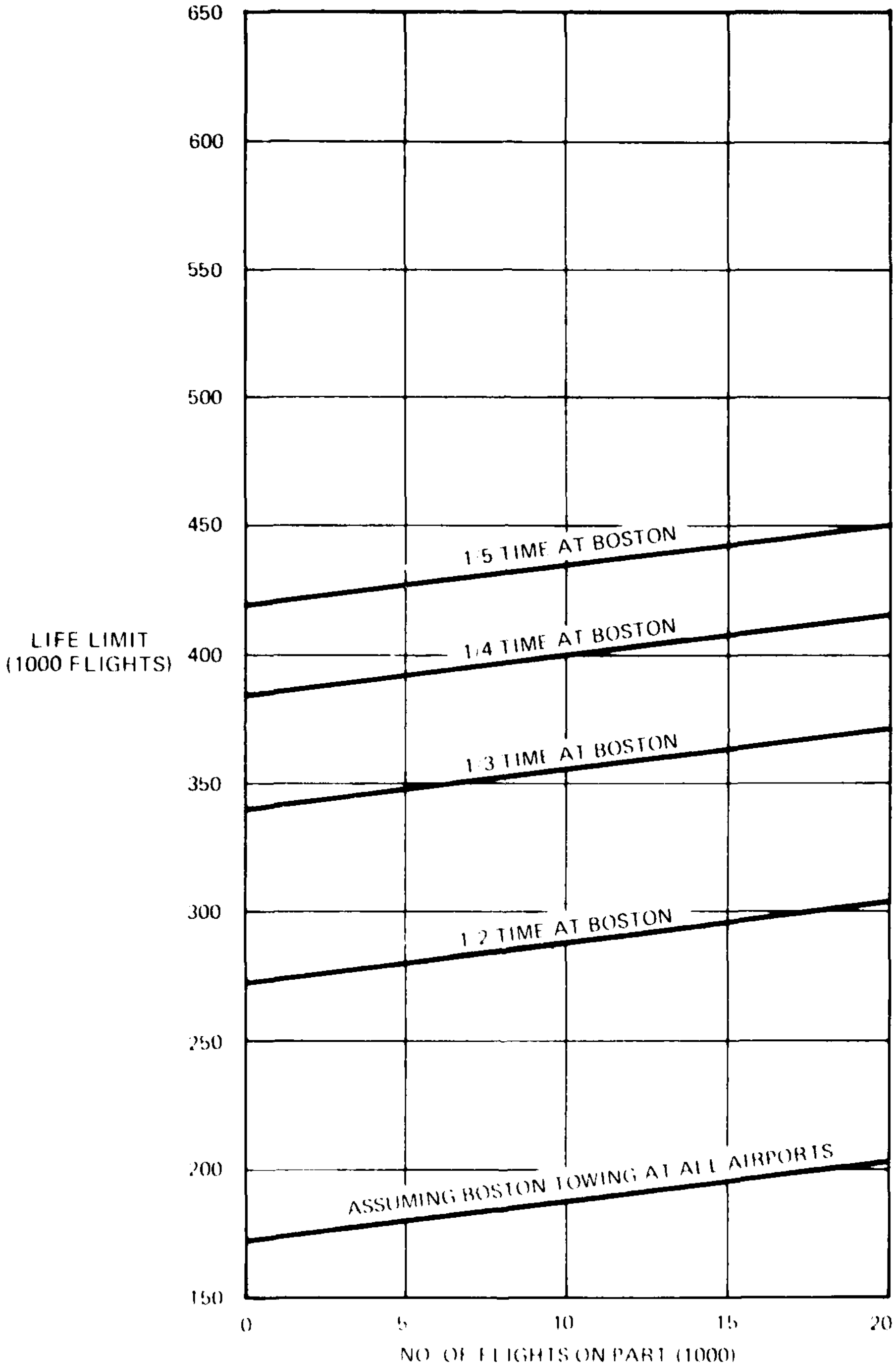


FIGURE 35. DC-9 SERIES 50 PART NO. 5927079, HOUSING

inspection of this area would be sufficient to preclude a severe fatigue problem.

ANALYSIS-SUMMARY

A summary of the life limits calculated for the various components of the nose landing gear is shown in Tables 4, 5, and 6 for the DC-9 Series 10, Series 30 and Series 50 respectively. As can be seen some parts associated with high-time aircraft would require evaluation in the near future if the aircraft is operated at Boston 1/2 of the time. It must be emphasized that the life limits presented herein are directly related to the number of flights accumulated by the component in question at the time towing is initiated at Boston and the degree of exposure to the additional towing (% of time at Boston). Any method of towing which would reduce the loads associated with the nose gear would dramatically increase the life limits presented herein. A relatively small reduction in loads (stresses) results in greatly increased life (cycles). The fatigue damage calculated in this report is almost entirely the result of the "moderate" and "hard" maneuvers. If the tow bar loads introduced to the nose gear could be limited to approximately 5% of the aircraft gross weight the life limits of the nose gear components would be dramatically increased above those indicated in this report.

It must be pointed out that these life limits are presented only to provide a basis for comparison. These limits are not approved by the FAA and are not to be considered true life limits. If the Boston towing regime were adopted, a complete analysis would be required and submitted to the FAA for approval. Several parts analyzed herein have life limits determined based upon fleet experience. This concept would require FAA approval.

TABLE 4
DC-9 SERIES 10 NOSE GEAR COMPONENT LIFE LIMITS

PART NO.	ITEM	NUMBER OF FLIGHTS ON PART	NUMBER OF FLIGHTS — PERCENT OF TIME AT BOSTON				
			FULL TIME*	1/2 TIME	1/3 TIME	1/4 TIME	1/5 TIME
5912733-1	LOWER DRAG BRACE	NEW PART 24,000 40,000	31,000 36,000 41,000	48,000 54,000 59,000	59,000 65,000 69,000	66,000 72,000 76,000	72,000 77,000 81,000
5912595-1, -2	UPPER DRAG BRACE	NEW PART 24,000 40,000	30,000 35,000 40,000	47,000 53,000 58,000	58,000 64,000 68,000	65,000 71,000 75,000	71,000 76,000 80,000
5927071 5928678	HOUSING	NEW PART 24,000 40,000	50,000 58,000 66,000	79,000 90,000 98,000	98,000 109,000 118,000	112,000 122,000 130,000	123,000 132,000 140,000
4912593 -501	PIN-END, CROSS TUBE	NEW PART 24,000 40,000	31,000 36,000 42,000	50,000 57,000 64,000	64,000 71,000 77,000	73,000 81,000 86,000	81,000 88,000 93,000
2912726	KNEE HINGE NUT	NEW PART	UNLIMITED LIFE				
4912734-1	KNEE HINGE BOLT	NEW PART 40,000	10,200 13,800	16,800 21,400	21,400 26,200	24,800 29,500	27,400 31,900
4912734 -501	KNEE HINGE BOLT	NEW PART 40,000	16,500 22,300	27,000 34,200	34,200 41,500	39,400 46,600	43,400 50,200
3958414	SHOULDER-DRAG BRACE BOLT	NEW PART 40,000	30,200 40,000	47,000 57,600	57,600 67,900	65,000 74,500	70,400 79,200

*FULL TIME ASSUMES THAT BOSTON TOWING OPERATION OCCURS AT ALL AIRPORTS.

TABLE 5
DC-9 SERIES 30 NOSE GEAR COMPONENT LIFE LIMITS

PART NO.	ITEM	NUMBER OF FLIGHTS ON PART	NUMBER OF FLIGHTS — PERCENT OF TIME AT BOSTON				
			FULL TIME*	1/2 TIME	1/3 TIME	1/4 TIME	1/5 TIME
5920210-1	LOWER DRAG BRACE	NEW PART	76,000	118,000	145,000	163,000	176,000
		24,000	89,000	133,000	160,000	176,000	189,000
		40,000	100,000	145,000	170,000	187,000	198,000
5920209 -501, -502	UPPER DRAG BRACE	NEW PART	26,000	40,000	49,000	55,000	60,000
		24,000	30,000	45,000	54,000	60,000	64,000
		40,000	34,000	49,000	58,000	63,000	67,000
5927079 5929601	HOUSING	NEW PART	300,000	470,000	580,000	660,000	715,000
		24,000	350,000	530,000	640,000	715,000	768,000
		40,000	395,000	580,000	688,000	758,000	808,000
4912593 -501	PIN-END, CROSS TUBE	NEW PART	19,000	31,000	40,000	46,000	51,000
		24,000	23,000	36,000	44,000	51,000	55,000
		40,000	26,000	40,000	48,000	54,000	59,000
2912726	KNEE HINGE NUT	NEW PART	UNLIMITED LIFE				
4920206	KNEE HINGE BOLT	NEW PART	25,000	40,700	51,600	59,600	65,600
		40,000	33,600	51,600	62,800	70,400	76,000
3920626	SHOULDER-DRAG BRACE BOLT	NEW PART	31,700	49,400	60,600	68,400	74,100
		40,000	41,700	60,600	71,400	78,400	83,300

*FULL TIME ASSUMES THAT BOSTON TOWING OPERATION OCCURS AT ALL AIRPORTS.

TABLE 6
DC-9 SERIES 50 NOSE GEAR COMPONENT LIFE LIMITS

			NUMBER OF FLIGHTS				
			PERCENT OF TIME AT BOSTON				
PART NO.	ITEM	NUMBER OF FLIGHTS ON PART	FULL TIME*	1/2 TIME	1/3 TIME	1/4 TIME	1/5 TIME
5920210-1	LOWER DRAG BRACE	NEW PART	31,000	48,000	59,000	67,000	72,000
		8,000	33,000	50,000	61,000	68,000	74,000
		24,000	36,000	54,000	65,000	72,000	77,000
5920209-501, -502	UPPER DRAG BRACE	NEW PART	7,500	11,800	14,600	16,600	18,100
		8,000	7,900	12,300	15,200	17,100	18,600
		24,000	8,800	13,400	16,200	18,100	19,500
5927079	HOUSING	NEW PART	172,000	273,000	340,000	386,000	420,000
		8,000	181,000	284,000	350,000	397,000	431,000
		24,000	202,000	309,000	375,000	420,000	453,000
4912593-501	PIN-END, CROSS TUBE	NEW PART	13,000	21,000	26,000	31,000	34,000
		8,000	13,400	21,800	27,500	31,600	34,800
		24,000	15,000	23,900	29,700	33,800	36,900
2912726	KNEE HINGE NUT	NEW PART	286,000	444,000	545,000	615,000	667,000
		8,000	800,000	462,000	563,000	632,000	682,000
		24,000	333,000	500,000	600,000	667,000	714,000
4920206	KNEE HINGE BOLT	NEW PART	16,300	26,700	33,900	39,300	43,300
		24,000	19,300	30,600	38,100	43,300	47,300
3920626	SHOULDER-DRAG BRACE BOLT	NEW PART	22,200	34,600	42,400	47,900	51,900
		24,000	25,900	38,900	46,700	51,900	55,600

*FULL TIME ASSUMES THAT BOSTON TOWING OPERATION OCCURS AT ALL AIRPORTS

V. OPTIONS

A review of Tables 4, 5 and 6 indicates that the immediate effect of the proposed towing at Boston-Logan, if adopted, would be minimal. The immediate or short-term areas of concern would be those parts which have already accumulated a high number of flights. Two options are available as concerns these parts. One would be to replace them with new parts or with parts which have fewer accumulated flights. The other option would be to reroute the aircraft on which these parts are installed so as to reduce their exposure to the Boston towing regime.

The long-term effects of the additional towing, as proposed at Boston-Logan, would be much more extensive. Depending upon aircraft utilization by the airlines involved (i.e., percent of operations at Boston), periodic replacement, and/or inspection of the affected parts would be required. There are several options which are available which would ensure the safety of operations.

1. OPTION 1 - AIRCRAFT ASSIGNMENT

Aircraft and/or parts which have accumulated substantial flights and are currently operated at Boston could be rotated with other aircraft and/or parts in the airline fleet which have fewer accumulated flights. The purpose is to expose parts with fewer accumulated flights to the Boston towing regime instead of the high-time parts. This procedure could pose considerable logistics problems for the airlines involved. This procedure could, however, allow the airlines flexibility in determining which option would be most cost effective. This procedure could solve any immediate problems which may arise when towing is initiated at Boston.

2. OPTION 2 - REMOVE, INSPECT AND/OR REPLACE

The second option would be to simply remove, inspect, and/or replace the affected part. The parts could be periodically replaced as their life limit is approached. The cost of such a remove and replace option for some specific nose landing gear components is given in Table 7. An alternate

TABLE 7
LABOR AND MATERIAL COSTS PER AIRCRAFT –
REMOVE AND REPLACE WITH NEW PART

TYPE OF AIRCRAFT	PART NO.	ITEM	QUANTITY PER AIRCRAFT	COST PER AIRCRAFT (DOLLARS)		
				LABOR	MATERIAL	TOTAL
DC-9 SERIES-10	5912733	LOWER DRAG BRACE	1	121	1,059	1,180
	5912595	UPPER DRAG BRACE	2	432	26,362	26,794
	4912593	PIN-END, CROSS TUBE	2	106	432	538
	4912734	KNEE HINGE BOLT	1	105	121	226
	3958414	SHOULDER-DRAG BRACE BOLT	1	70	147	217
DC-9 SERIES-30	5920210	LOWER DRAG BRACE	1	121	1,414	1,535
	5920209	UPPER DRAG BRACE	2	432	14,400	14,832
	4912593	PIN-END, CROSS TUBE	2	106	432	538
	4920206	KNEE HINGE BOLT	1	105	121	226
	3920626	SHOULDER-DRAG BRACE BOLT	1	70	363	433
DC-9 SERIES-50	5920210	LOWER DRAG BRACE	1	121	1,414	1,535
	5920209	UPPER DRAG BRACE	2	432	14,400	14,832
	4912593	PIN-END, CROSS TUBE	2	106	432	538
	4920206	KNEE HINGE BOLT	1	105	121	226
	3920626	SHOULDER-DRAG BRACE BOLT	1	70	363	433

to replacing the parts would be to periodically inspect them for fatigue damage. The inspection period for all affected parts would not necessarily be the same. Some would require inspection more frequently than others. These inspection intervals would be determined by acceptable means using damage tolerant design practices and/or tests. Determination of specific inspection intervals for the parts in question was not considered within the scope of this report. Typical cost figures for removal, inspection and reinstallation are given in Table 8 for some representative nose landing gear components.

3. OPTION 3 - TESTS

The third option under consideration is one of testing the DC-9 nose landing gear using the loads model developed in this report. Such testing could be accomplished in two ways. One would be to fatigue test a complete nose gear assembly to all the loads associated with the nose landing gear including the towing as envisioned at Boston. This type of test is desirable from the standpoint of having all the nose gear structure subjected to the appropriate loads, deflections and interactive effects associated with the actual gear. It is felt that the DC-9 nose landing gear and its supporting structure is inherently more fatigue resistant than is shown by analysis in this report. The only acceptable method of determining the true fatigue strength is to perform a test incorporating the expected service loads. A test of this nature would be relatively expensive and would require approximately 30000 to 50000 man hours.

Another approach would be to test individual gear components separately. This approach could be used for the drag brace system. The input loads would be those associated with the lower drag brace and would be determined using the loads obtained herein and any additional loading conditions considered to cause fatigue damage in the drag brace system. This type of testing would be less expensive than that previously mentioned but since the entire gear would not be represented, allowances would need to be

TABLE 8
LABOR AND MATERIALS COST PER AIRCRAFT – INSPECTION, REMOVE, AND REPLACE WITH ORIGINAL PART

TYPE OF AIRCRAFT	PART NO.	ITEM	QUANTITY PER AIRCRAFT	LABOR COSTS PER AIRCRAFT (DOLLARS)		
				REMOVE AND REPLACE	INSPECTION	TOTAL
DC-9 SERIES 10	5912733	LOWER DRAG BRACE	1	121	17	138
	5912595	UPPER DRAG BRACE	2	432	70	502
	4912593	PIN-END, CROSS TUBE	2	106	34	140
	4912734	KNEE HINGE BOLT	1	105	17	122
	3958414	SHOULDER-DRAG BRACE BOLT	1	70	17	87
DC-9 SERIES 30	5920210	LOWER DRAG BRACE	1	121	17	138
	5920209	UPPER DRAG BRACE	2	432	70	502
	4912593	PIN-END, CROSS TUBE	2	106	34	140
	4920206	KNEE HINGE BOLT	1	105	17	122
	3920626	SHOULDER-DRAG BRACE BOLT	1	70	17	87
DC-9 SERIES 50	5920210	LOWER DRAG BRACE	1	121	17	138
	5920209	UPPER DRAG BRACE	2	432	70	502
	4912593	PIN-END, CROSS TUBE	2	106	34	140
	4929206	KNEE HINGE BOLT	1	105	17	122
	3920626	SHOULDER-DRAG BRACE BOLT	1	70	17	87

made to account for this fact. This type of test would require approximately 20 to 25% of the man hours needed to accomplish a full scale test.

4. OPTION 4 - ALTERNATIVE TOWING

In addition to the above mentioned options other methods and concepts in towing are investigated. Historically the airlines have been concerned about employing a safe, efficient and economical aircraft ground movement system. At the present time taxiway movements of any distance primarily depend on aircraft self-propulsion and, from the standpoint of time required, are impressively efficient. Changes to this procedure, unless carefully implemented would increase the time required for airport arrival and departures.

The material summarized under this option investigates several concepts in aircraft ground movement. The assumption is that the feasibility of developing a mover system must comply with environmental requirements and ultimately result in dollar savings. This section is not intended to derive the optimum method for aircraft movers but to present the best information available on which to base a comprehensive study that is technically possible and operationally desirable.

a. POWERED MAIN LANDING GEAR (INTEGRAL SYSTEM)

One of the most attractive techniques for moving aircraft on the ground without use of the main engines would be to incorporate an internal drive system to the main landing gear of the aircraft. Considering the high % of aircraft gross weight on the main landing gear this seems like a practical approach to deal with the low tractive coefficients in adverse weather. Other advantages aside from noise, pollution emission reductions, and jet blast problems are elimination of time requirements for attaching/detaching tow vehicles to the aircraft. With the capability for reverse, as well as forward operation, there would be less congestion in the terminal area and a reduction in requirements for airport service vehicles. The most apparent disadvantages would be a reduction in aircraft payload and relatively high cost of retrofitting such a system to aircraft now in service. Boeing has estimated that added weight for a 727 type aircraft, for drive and installation of a high capacity APU, would be approximately 1,000 pounds. This would provide 100 HP to the landing gear wheels and permit a ground speed of about 10 mph.

b. POWERED MAIN LANDING GEAR (GROUND VEHICLE SYSTEM)

In this system the towing tractor consists of a leading power element joined to a trailing twin boom assembly. Torque is applied directly to the main landing gear. The tractor generates all power required for traction. The aircraft nose landing gear would fit into a wheel unloading device just aft of the tractor and steering would be accomplished by yawing the power inputs to the main landing gear wheels. This concept like the integral system utilizes the aircraft weight to develop traction and braking force. Another advantage is that the weight penalty to the aircraft would be less than the integral system. The primary disadvantages to the concept would be the complexity of developing a system configuration.

c. POWERED NOSE LANDING GEAR

This concept is a Lockheed Aircraft service design for drive/braking the aircraft. This towbar-like device would offer means to drive the nose gear wheels with a relatively standard lightweight tractor. Basically the system consists of a towbar with a drive motor which drives the aircraft nose gear. Power to the drive motor is supplied from the towing tractor. Steering the aircraft requires tractor and cockpit operator coordination with aircraft power. The advantages to this concept are the relatively low cost and little retrofitting such a system to the aircraft. The most apparent and perhaps decisive disadvantage is the low percentage of aircraft weight borne by the DC-9 nose gear. Because of the possibility of low tractive coefficients on airport paved surfaces during adverse weather conditions, powering the nose gear does not seem to be a practical system as a prime mover of aircraft.

d. STEERING TOWBAR

An effective method of providing towbar actuated steering has been conceived which is a ball-socket joint used as the towbar/aircraft interface. The socket fitting is mounted integrally in the aircraft bottom fuselage structure. This socket is capable of handling all towing loads imposed by the ball fitting on the towbar. External pins on the ball will transmit steering torque through a compact universal joint arrangement to a cable drum in the aircraft, which will in turn actuate steering valves which control the position of the nose landing gear. No disconnect of normal cockpit steering controls will be required. The only requirement is that hydraulic power from the aircraft be available. Apparent disdavantage would be high cost of retrofitting such a system to aircraft now in service.

e. TOWBAR

This concept incorporates conventional towing and pushing forces through a rigid towbar. Steering is a coordinated function between the tractor driver and responsible personnel in control of the aircraft. It is assumed that towing practices will not produce forces which exceed towing force limits. To avoid damage to the aircraft the towbar can be designed with shear pins. The problem with shear pins is after the pin has sheared, on most designs, the aircraft towing fitting can still be over-stressed by continued operation against the retaining pin. Also, in most cases, only partial steering control is retained. Warning devices on conventional towbars consist of mechanical pins, flags and flashing beacon. Also available are shock absorbing devices to help damp shocks induced during start and stopping. In this system of moving aircraft the responsibility for safe and effective operation lies with the selection and training of personnel.

f. PARTIAL LIFT TRACTORS

There have been many concepts developed in which the aircraft mover takes advantage of the aircraft weight. One design involves a towing tractor equipped with a hydraulically movable ball assembly located on the upper structure of the tractor. With the tractor positioned under the aircraft the ball assembly is raised into a socket located on the underside of the aircraft. Vertical extension of the ball assembly is continued until the nose landing gear is unloaded and a portion of aircraft weight is transferred to the tractor to aid in tractive effort.

Two other designs worth mentioning are the Chrysler's tractor and the Secmaker tractor. In the Chrysler's concept the tractor is backed up to the aircraft then a special jacking mechanism lifts the airplane nosewheel off the ground thereby adding the nose wheel load to the tractor. In the Secmaker concept the tractor backs up to the aircraft until a ramp slides under the nose wheel, almost at the same time raising the ramp hydraulically and inclining it continuously towards the center of the tractor. The coupling process ends with the nose wheel resting on the tractor's rotating platform and being fastened by special locking system. Designed for speeds up to 44 mph the Secmafer tractor was able to tow a Boeing 747 at 32 mph. Should the pilot decide to make an emergency stop, he can do so by full application of the brakes; the nose gear then disengages from tractor and rolls down the ramp onto the ramp. For forward loads on the nose gear a sensor at a preset load automatically applies the tractor brakes. Other advantages claimed by Secmafer, with the nose gear platform free to rotate lateral loads are eliminated. Also "jack-knifing on ice" need not be serious, the tractor could rotate about the nose gear without damaging the aircraft.

The most obvious advantgage of these concepts is the utilizing of aircraft weight to gain traction and elimination of towbar and shear pin. Another advantage is the elimination of coordination requirement between tractor and aircraft. Two obvious disadvantages are the cost of the vehicles and the other is the problem of size. They are not capable of push from underneath the aircraft, a standard practice at some airports. There would have to be a change of tractor after the push back was completed.

g. COORDINATED BRAKING

A new concept has been proposed by the Douglas Aircraft Company for one DC-9 aircraft, which would allow the flight crew to control braking both for the towing vehicle and aircraft. Provisions can be incorporated into the towing system which when the aircraft brakes are applied, an electrical signal through a cable attached to the underside of the aircraft from the towbar, would also apply braking to the tow vehicle. A conventional tow vehicle and tow bar can be modified to accept this concept. The major components for the aircraft are readily available and costs are at a practical level.

Retrofitting existing DC-9 aircraft with this system is possible at a relative low cost. The advantages of this concept are less nose gear strain, lower incidence of shear pin separation and shorter stopping distance with more control, especially on low friction surfaces.

h. SUMMARY

Among the possible methods studied, with the exception of the conventional towbar, all have been limited in proving the feasibility of the aircraft ground system. Studies have suggested advantages in noise and pollution reduction concepts and several companies have produced designs for suitable aircraft ground movements but, before a company will make a major investment in such equipment, guidelines must be established jointly by airport planners, aircraft manufacturers and airlines. Another important consideration would be a single organization to operate the aircraft ground system; the airport, a consortium of all the airlines or an outside company. In this way the equipment and manpower needed to operate the system would be kept to minimum and equipment would have maximum use 24 hours a day.

Until such programs can be justified economically, effort should be made towards improving available towing vehicles and towbars. It is less difficult to suppress noise and improve air pollution in ground equipment than the current generation of aircraft. Current design in tow vehicles and towbars should not be selected on the basis of cost, but on new features for improved safety, reliability and ease of use, etc. Suppliers are reluctant to spend time and money on innovative concepts unless they have a firm commitment that there is a market for their product.

VI CONCLUSION

The loads developed during the variety of towing conditions tested at Long Beach are considered representative of those loads likely to occur during normal service operations. The only significant loads encountered were those associated with the start and stop portions of the maneuvers. Loads due to runway/taxiway cross slopes and intersections, turning and steady-state towing were not considered significant.

The loads model developed using the loads obtained from the tests, observations at Boston-Logan and experience with other ground maneuvers is considered to adequately represent the DC-9 towing regime as envisioned at Boston-Logan. The loads of 5%, 8% and 12% of aircraft gross weight for "normal", moderate" and "hard" maneuvers are considered to be representative of those types of maneuvers without introducing undue conservatism. The percentage of time spent in these maneuvers; 80% for "normal", 17% for "moderate" and 3% for "hard" is considered to be representative of service conditions taking into account congestion, weather and the human element.

The analysis was conducted using the loads model for towing as developed herein and any additional conditions from the original analysis which were considered fatigue damaging. Where possible, the method used in the original analysis were used to calculate the new life limits considering the additional towing as described by the loads model. In cases where the life limit obtained by these methods was unrealistically low a "lead the fleet" concept was adopted. This concept considers the fleet experience gained and uses it to determine the life limits. A fleet experience of 40,000 flights was adopted for the DC-9 series 10 while 32,000 and 8,000 flights were used for the series 30 and 50 respectively. It is felt that enough experience has been gained by airplanes which have accumulated more than these numbers of flights to assume that individual DC-9 series 10 aircraft have experienced 40,000 tow cycles where as the series 30 and series 50 aircraft have 32,000 and 8,000 tow cycles respectively.

VI CONCLUSION (Continued

The analysis indicated that several nose landing gear components could be affected by the additional towing as proposed at Boston-Logan. The immediate effect would concern those aircraft which have already accumulated a large number of flights and are operated at Boston extensively.

The options available include re-assignment of aircraft to reduce exposure to the Boston towing regime. This could be a short-time solution for those aircraft which would be affected immediately. Other options would include removal and replacement of parts as their life limts are reached and periodic inspection of parts to detect fatigue damage.

Other methods of towing were investigated and descriptions of the various methods included.The single most important object in alternate methods of towing as concerns this report is to reduce the loads applied to the nose gear. A simple shock absorbing device built into existing tow bars would seem to be the most practical solution for the short term.

No such tow bar currently exists for the DC-9 and the design, manufacture and testing of one could take several months. The shock absorbing tow bar would require extensive testing to insure that the loads introduced at the nose gear are reduced significantly to ensure that the fatigue damage to the nose gear is reduced dramatically or eliminated.

ARTICLE V - <u>Certain Ground Movements By Jet And Turboprop Aircraft Not To Be Conducted By Self-Propulsion</u>

A. Definitions:

As used in this regulation the following terms are defined as follows:

1. <u>Aircraft Operating Movement:</u> Any movement of jet or turboprop aircraft on the ground directly to or from a runway in connection with a takeoff or landing by that aircraft.

2. <u>Aircraft Repositioning Movement:</u> Any movement of a jet or turboprop aircraft on the ground which is not an Aircraft Operating Movement.

B. Within the daily time periods established by the following compliance schedule, no aircraft repositioning movement shall be conducted by self-propulsion.

Compliance Schedule:

Commencing February 1, 1977 - 7:00 p.m. - 7:00 a.m.
Commencing July 1, 1977 - 24 hours per day

C. Within the daily time periods established by the following compliance schedule, no aircraft operating movement (except for arrivals or departures from South Terminal gates 4, 6, 8, 10, 12 and 13 shall be conducted by self-propulsion westerly of an area near the Airport Fire Station designated by the Airport Manager as the area for towing initiation (inbound) or towing termination (outbound).

Compliance Schedule: Departing Aircraft

Commencing February 1, 1977 - Midnight - 7:00 a.m.
Commencing April 1, 1977 - 11:00 p.m.-7:00 a.m.
Commencing July 1, 1977 - 7:00 p.m.-7:00 a.m.

Commencing January 1, 1978 this regulation shall apply to departing aircraft twenty-four hours per day. The Executive Director upon notice to be given not later than November 30, 1977 based on a finding that an extension is necessary to permit implementation of the program without undue congestion or delay, may extend until June 30, 1978 the commencement date for twenty-four hour application of this compliance schedule.

Compliance Schedule: Arriving Aircraft

Commencing February 1, 1977 - Midnight - 7:00 a.m.
Commencing July 1, 1977 - 11:00 p.m.-7:00 a.m.
Commencing October 1, 1977 - 7:00 p.m.-7:00 a.m.

Commencing January 1, 1978 this regulation shall apply to arriving aircraft twenty-four hours per day. The Executive Director upon notice to be given not later than November 30, 1977 based on a finding that an extension is necessary to permit implementation of the program without undue congestion or delay, may extend until June 30, 1978 the commencement date for twenty-four hour application of this compliance schedule.

D. An aircraft prohibited from using self-propulsion under this regulation shall not operate any engine used in propulsion while engaged in an aircraft operating movement or an aircraft repositioning movement.

E. Except in cases of a safety emergency, no tug or tractor shall tow an aircraft unless two-way radio communication is maintained with the Control Tower on appropriate frequencies in use.

F. Upon request, the Airport Manager may exempt from the restrictions on aircraft operating movements an aircraft which is not equipped with an APU.

G. The restrictions on aircraft operating movements and aircraft repositioning movements in this Article may be temporarily suspended by the Airport Manager if required to alleviate congestion or delays on the aircraft movement areas or be automatically suspended when snow, ice or slush on operating pavement surfaces impedes proper operation of towing procedures.

H. The operator of an aircraft with an inoperative APU may obtain a waiver permit from the Airport Manager for an aircraft operating movement.

I. The Executive Director shall maintain a program of monitoring and evaluation of towing for noise abatement purposes and shall periodically report his findings to the Authority.

APPENDIX B

This appendix contains photographs of typical test procedures and time history plots of the test parameters recorded during the towing tests at Long Beach Municipal Airport and the Douglas Aircraft Facility. The tests utilized a DC-9 Series 40 aircraft at a gross weight of 100000 lbs and a center of gravity position of 9% MAC.

Each time history plot contains the tow bar axial load, the side load at the two bar attach point to the tow vehicle and the nose wheel steering angle. The title of each figure describes the condition represented.

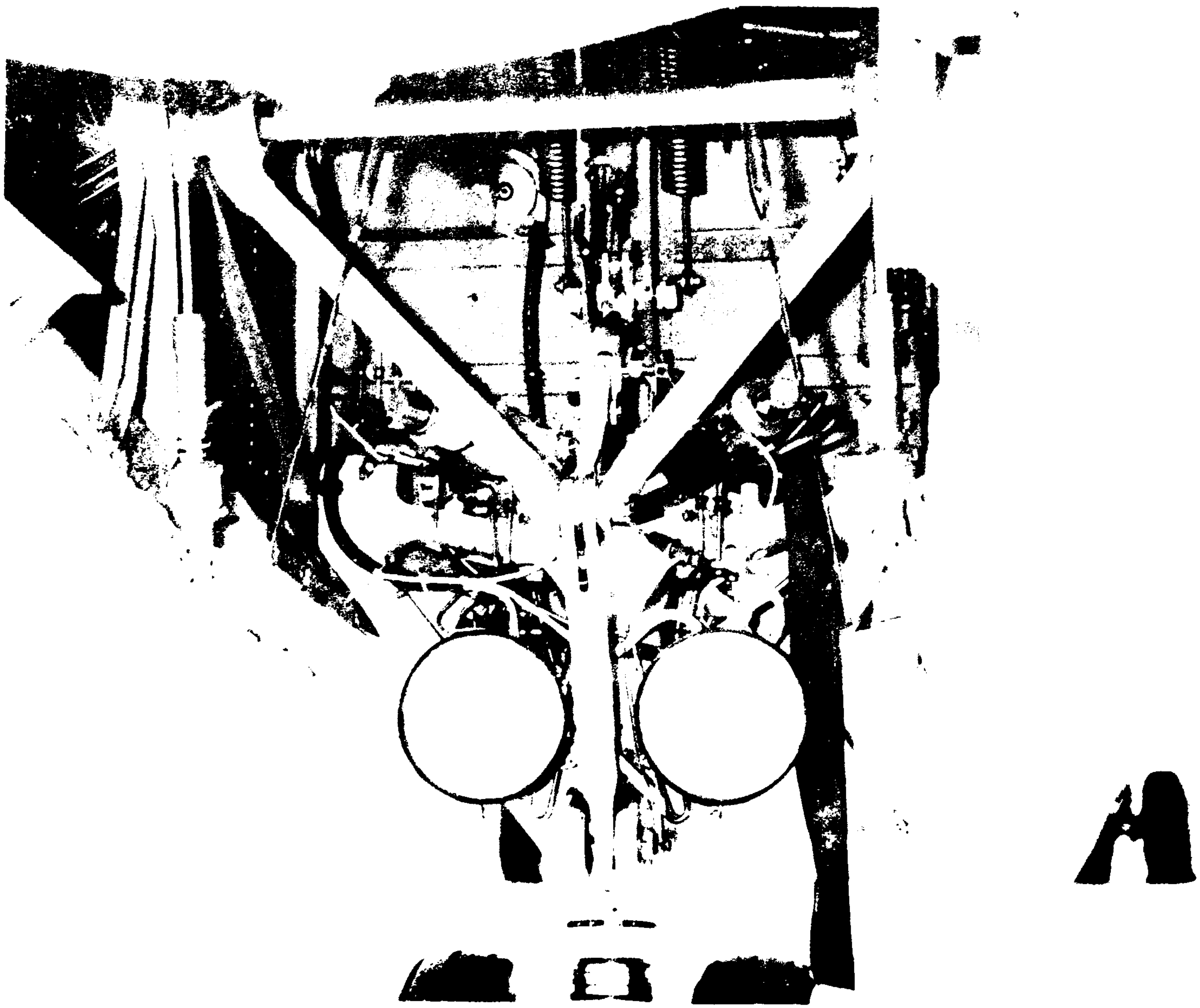


FIGURE B1. DC-9 NOSE LANDING GEAR

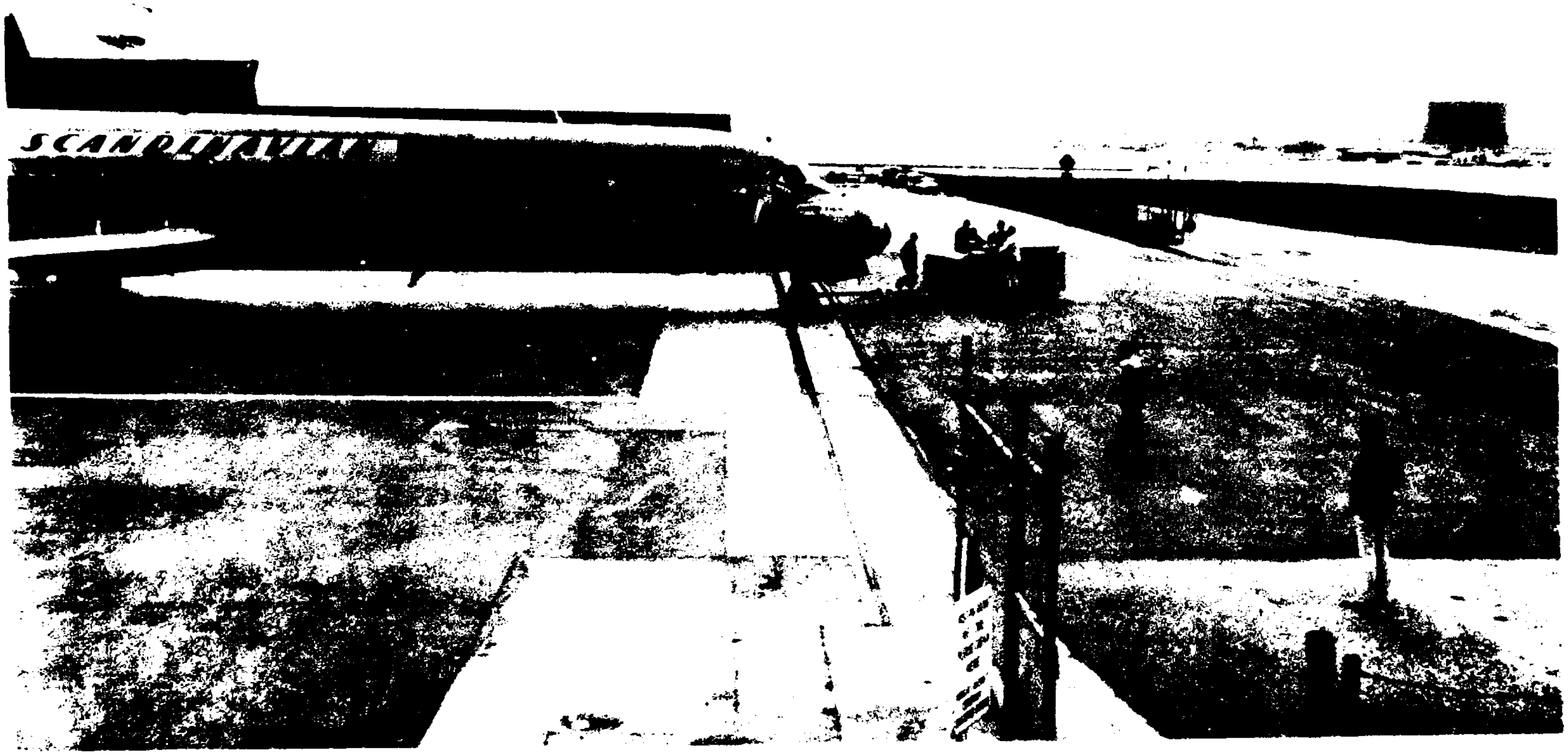


FIGURE B2. TOWING OVER GATE TRACKS (ROUGH SURFACE)

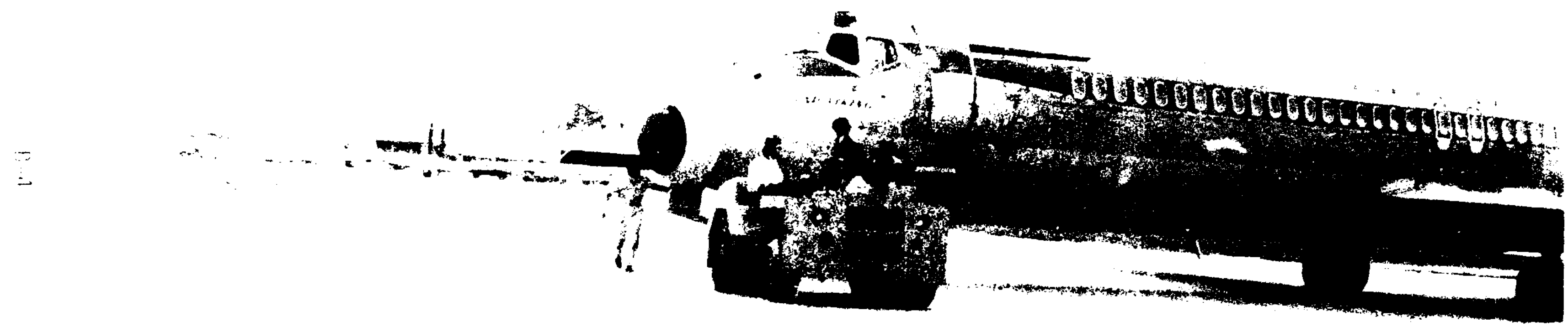


FIGURE B3. TYPICAL TURNING MANEUVER

FIGURE B4. NOSE GEAR ANGLE DURING TYPICAL TURNING MANEUVER

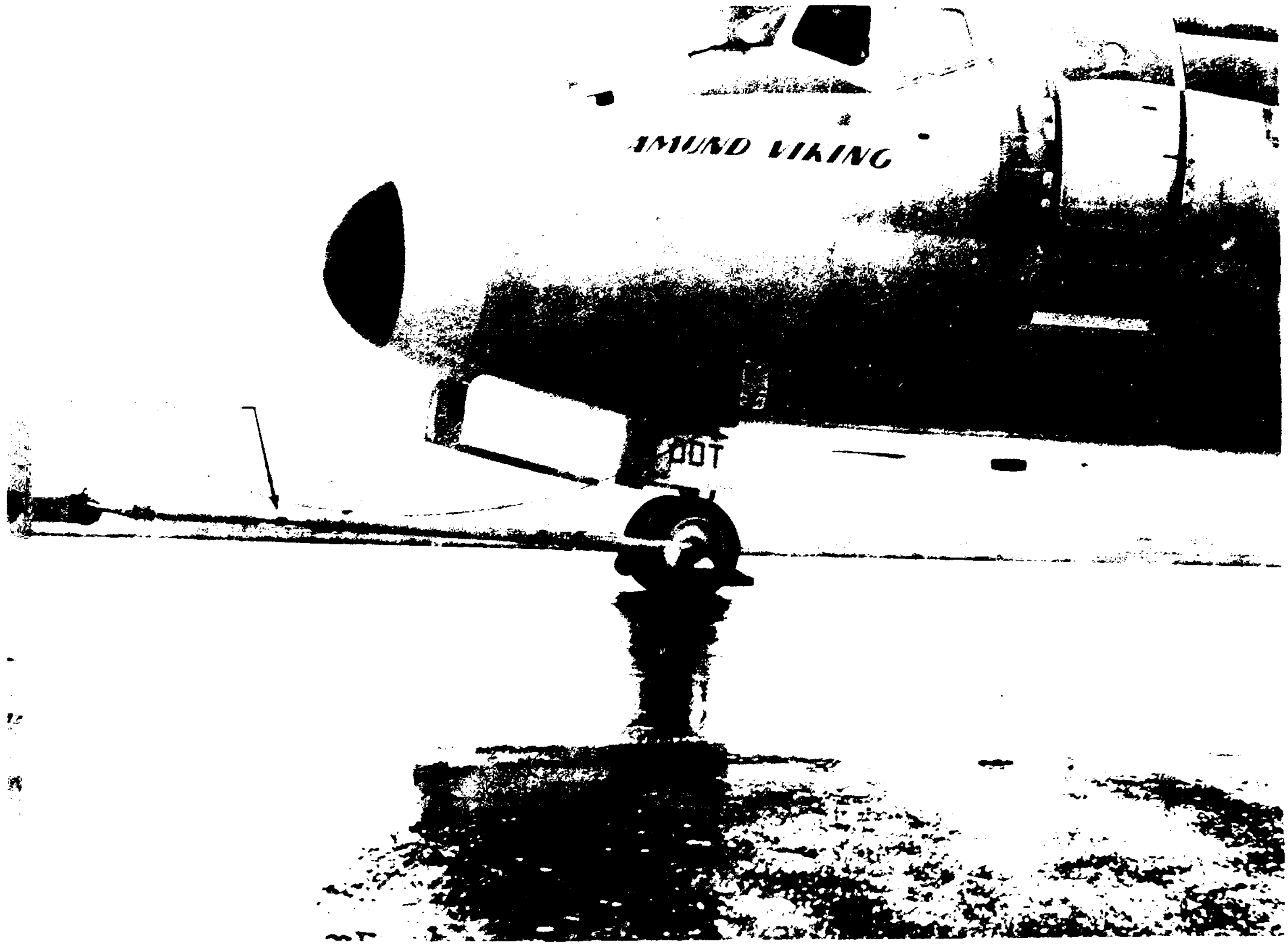


FIGURE B5. TOWING ON WET SURFACE

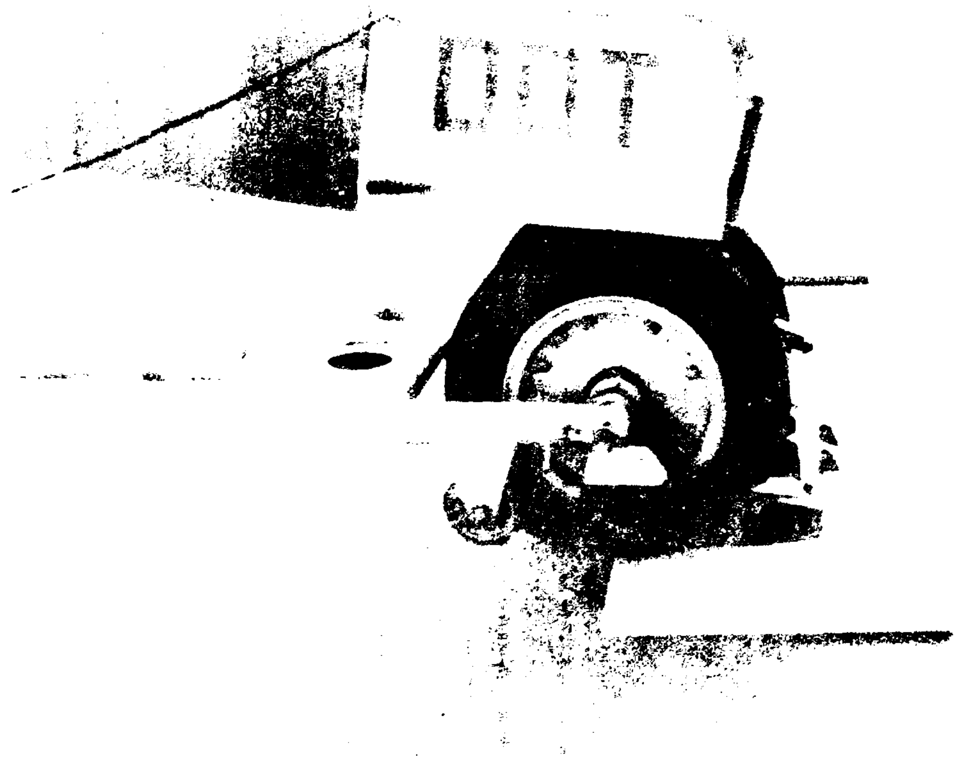


FIGURE B6. TOWING OVER "BUMP"

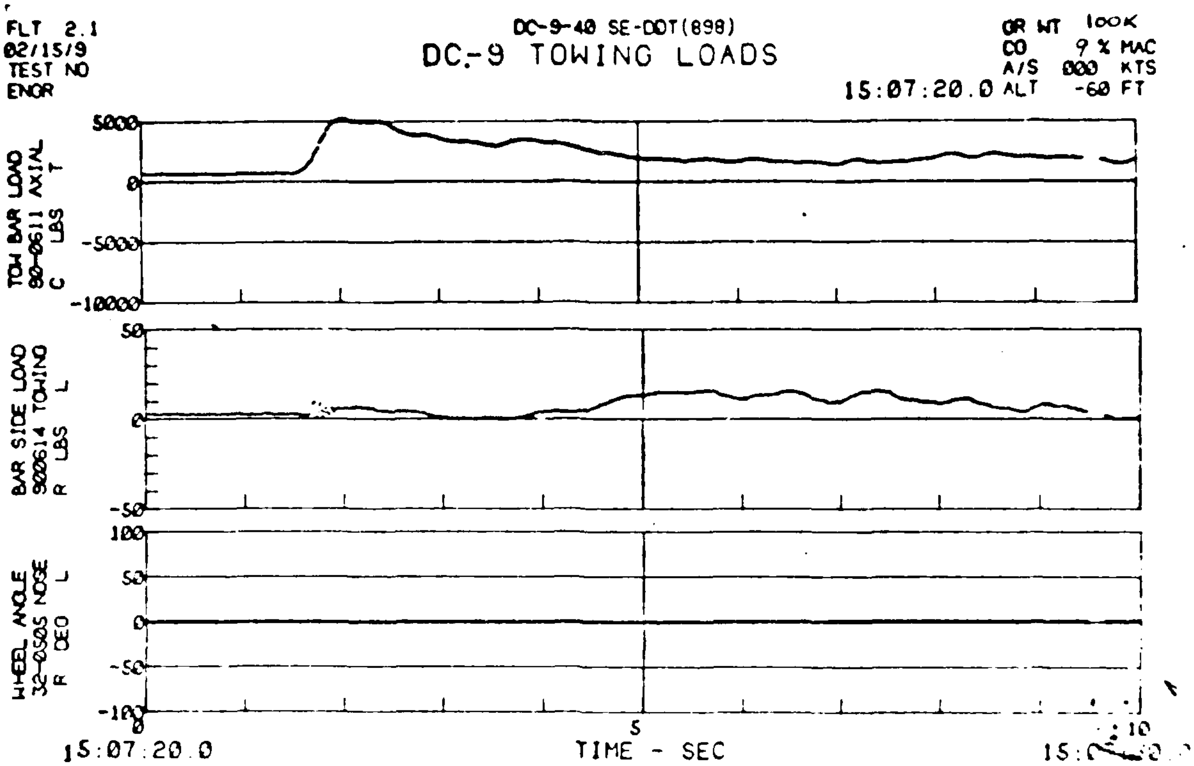


FIGURE B7 - NORMAL FORWARD TOW

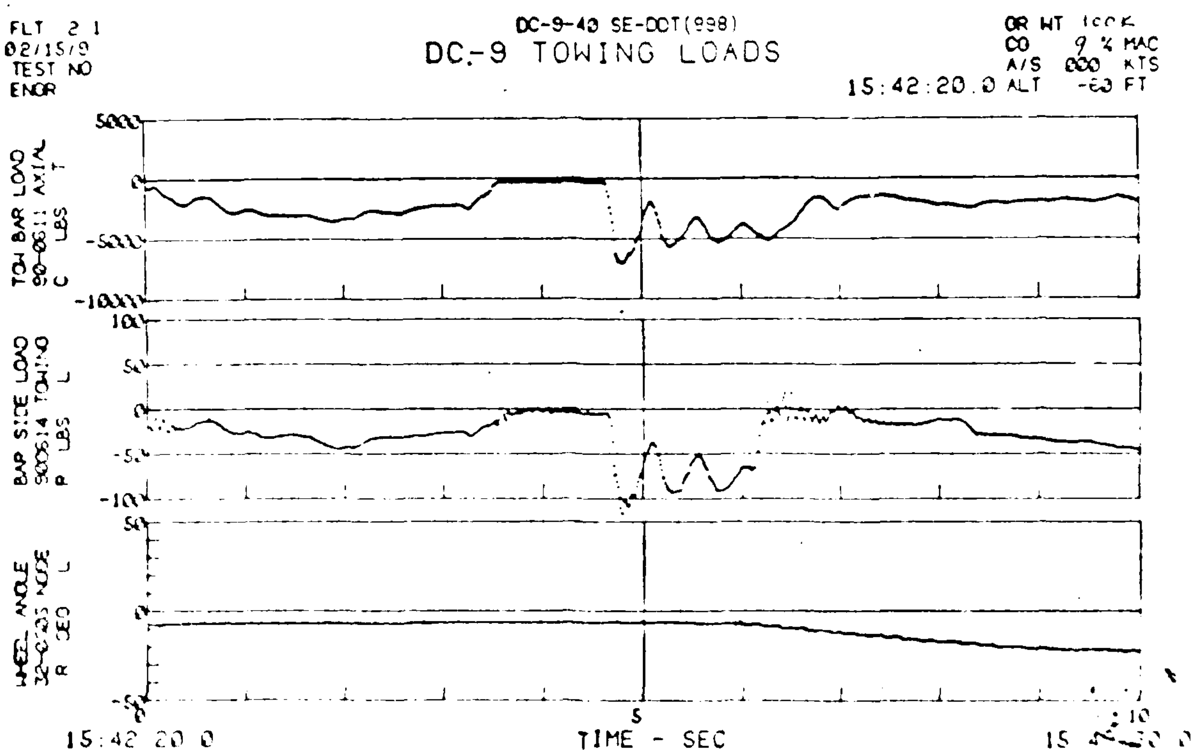


FIGURE B8 - NORMAL AFT TOW

AD-A086 864 DOUGLAS AIRCRAFT CO LONG BEACH CA F/G 1/2
EVALUATION OF THE IMPACT OF TOWING DC-9 TRANSPORT AIRPLANES AT --ETC(U)
MAY 80 E A HOOVER DOT-FA78WA-4198

UNCLASSIFIED FAA-NA-80-23 NL

2 OF 2
AD
A086864

END
DATE
FILMED
8-80
DTIC

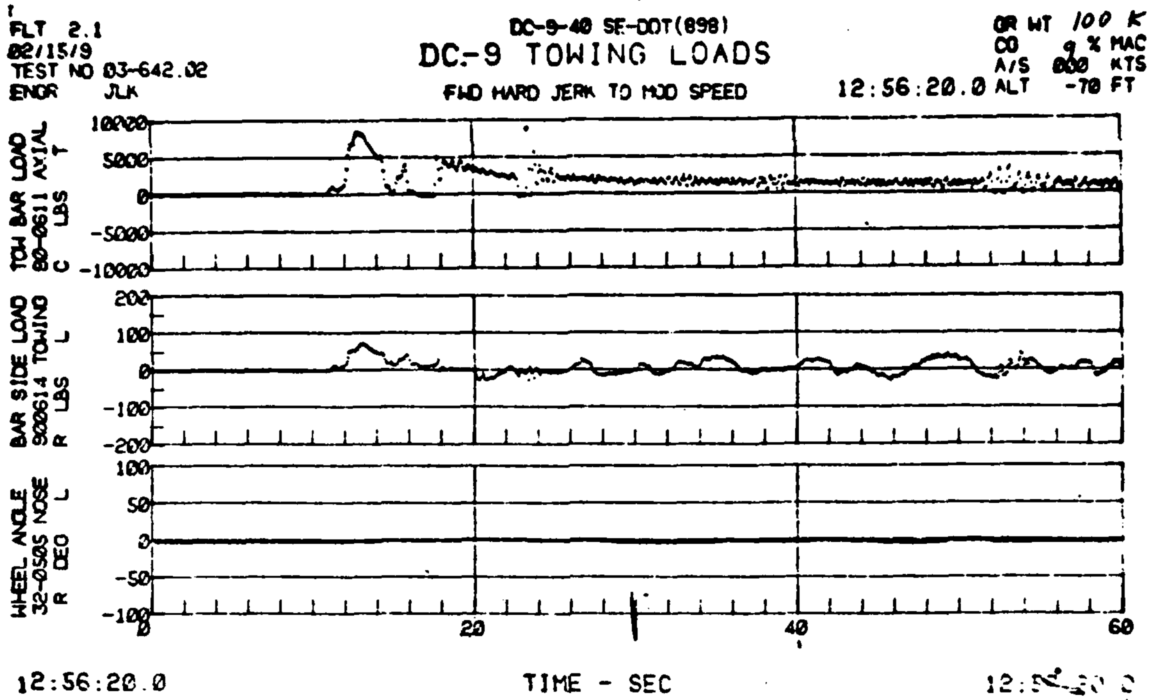


FIGURE B9 - FORWARD HARD JERK TO MODERATE SPEED

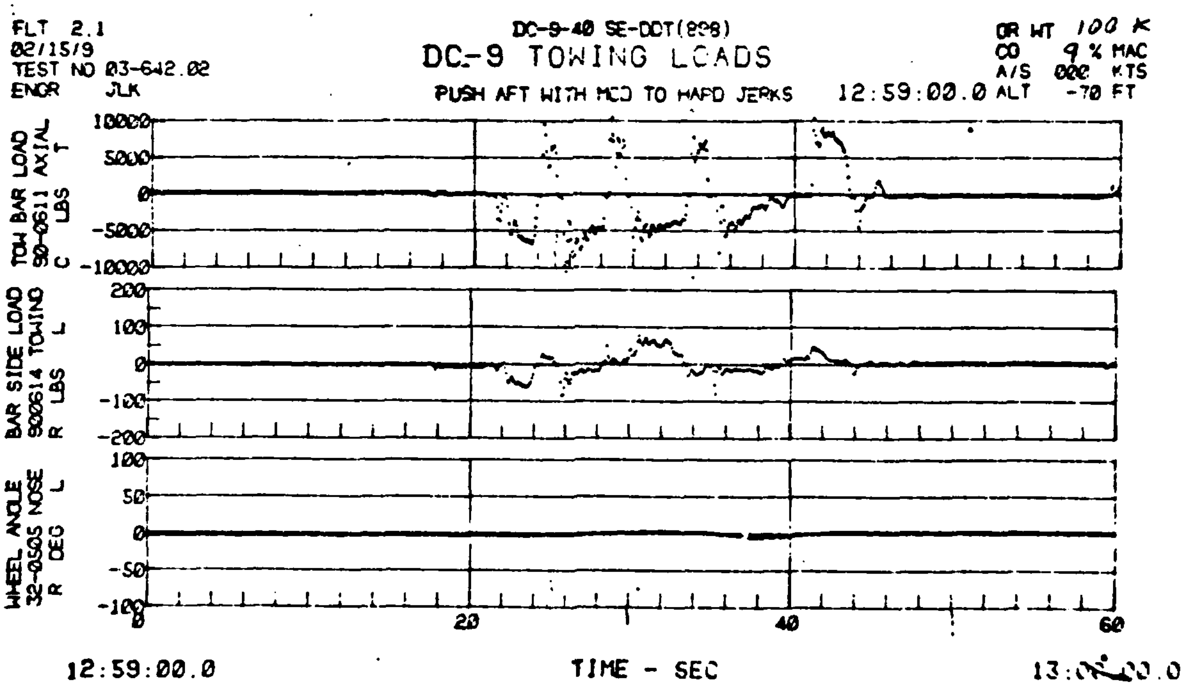


FIGURE B10 - PUSH AFT WITH MODERATE TO HARD JERKS

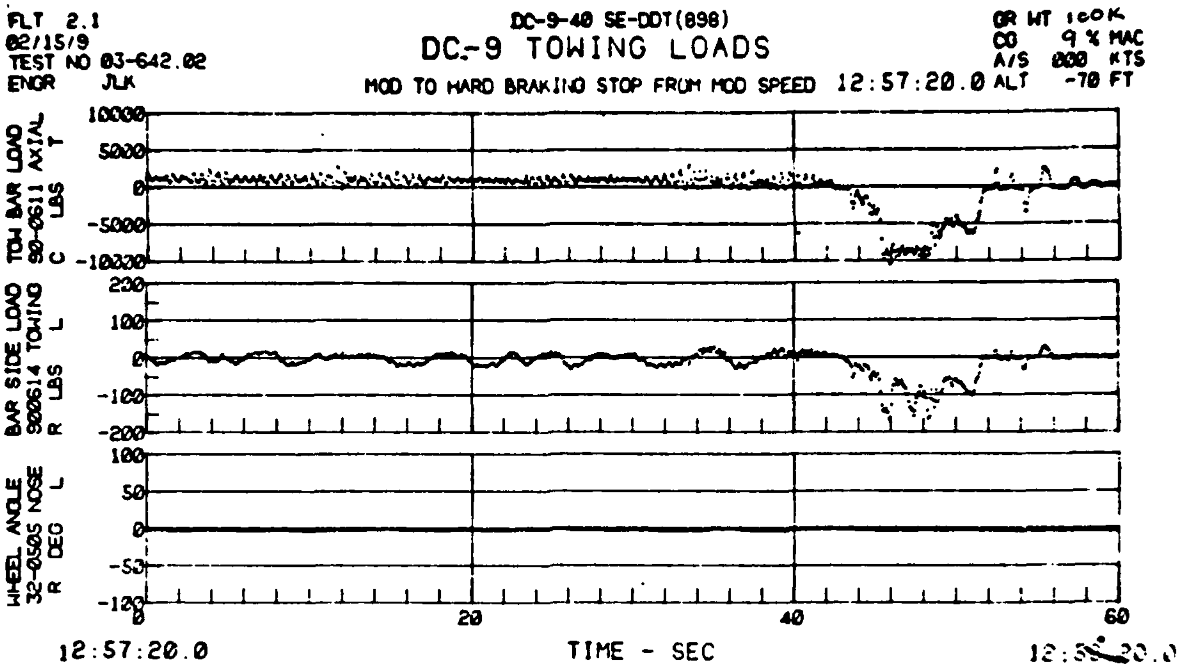


FIGURE B11 - MODERATE TO HARD BRAKING STOP FROM MODERATE SPEED

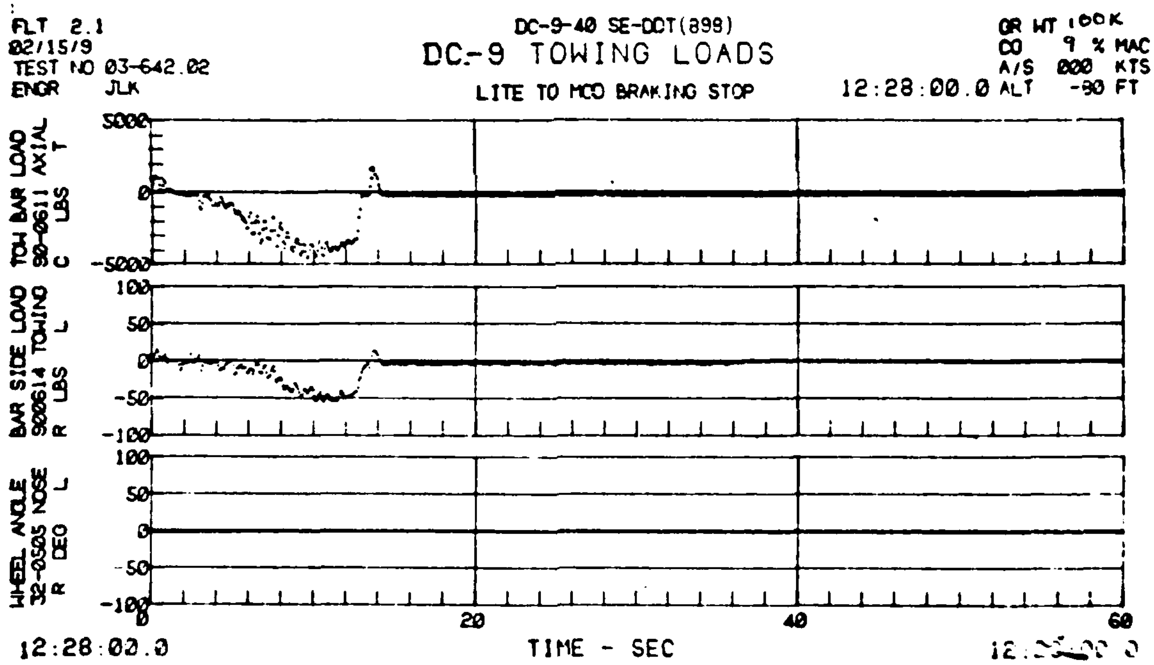


FIGURE B12 - LIGHT TO MODERATE BRAKING STOP

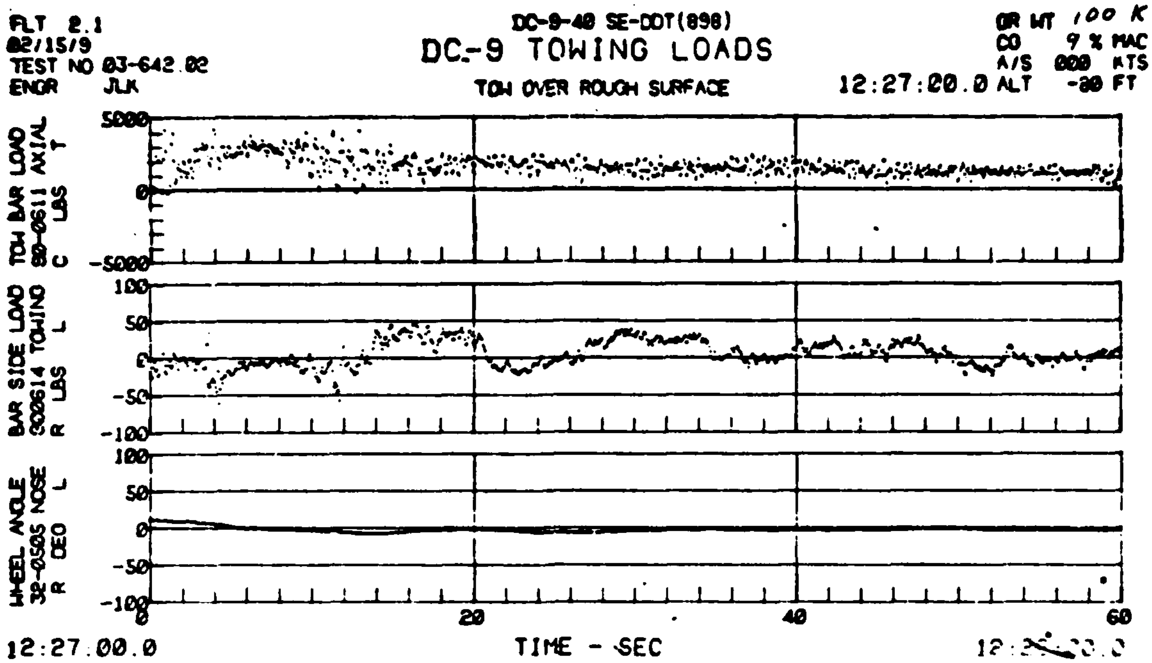


FIGURE B13 - TOW OVER ROUGH SURFACE

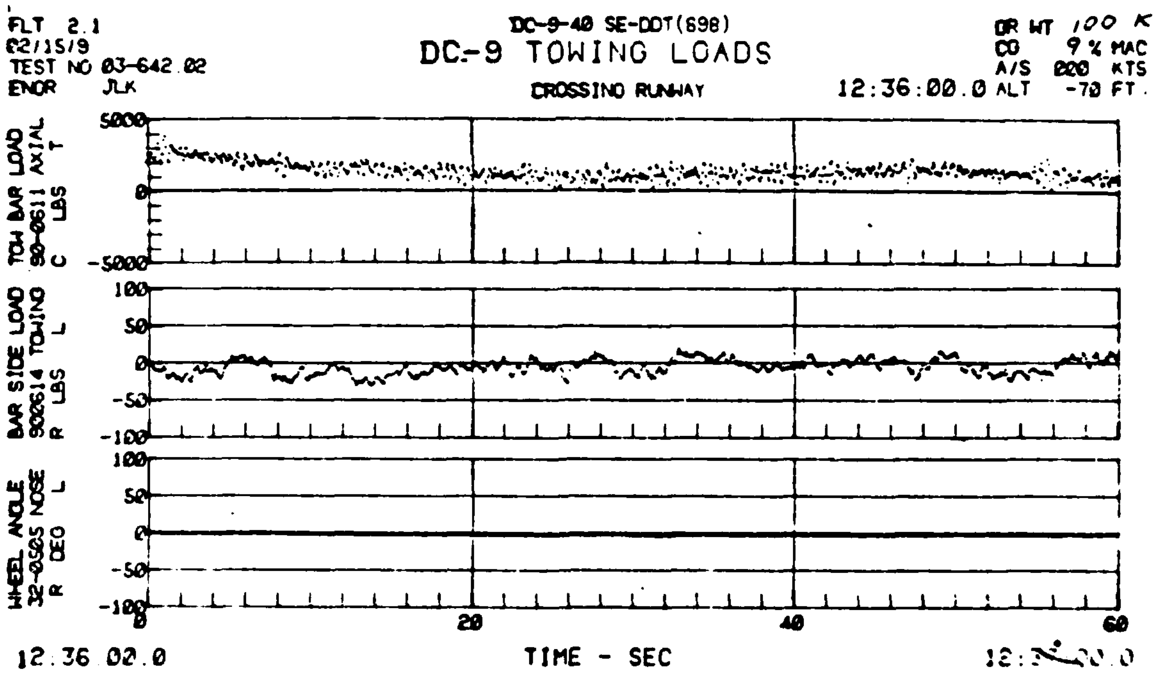


FIGURE B 14 - TOW OVER TAXIWAY, RUNWAY INTERSECTION

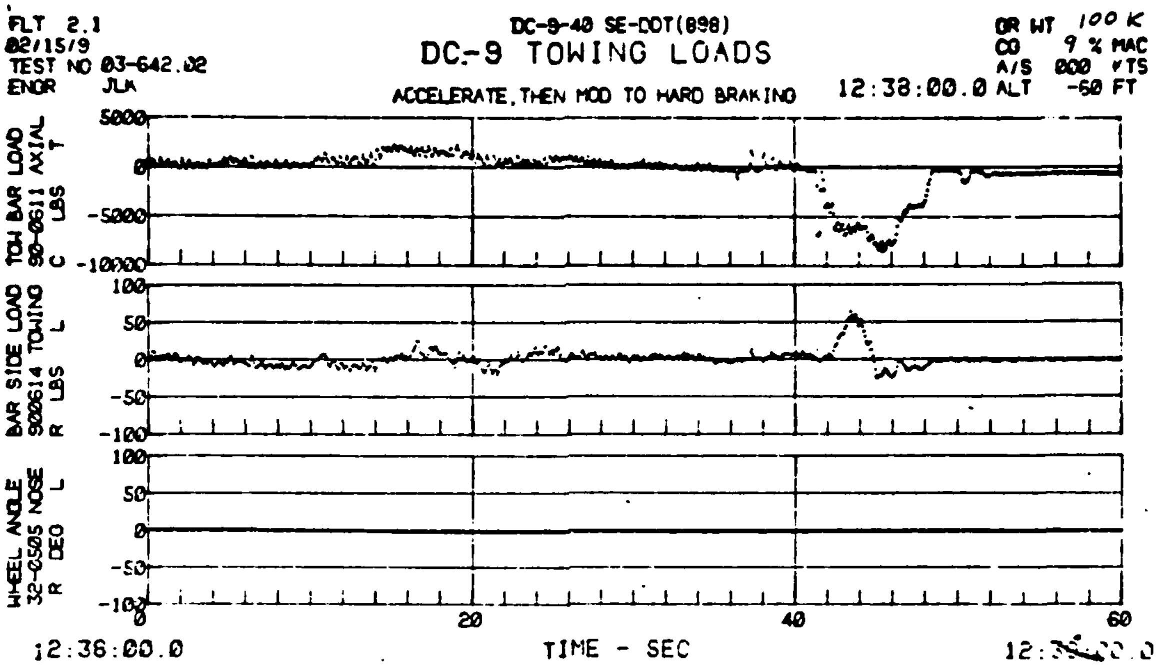


FIGURE B15 - ACCELERATE TO 8 KTS. THEN MODERATE TO HARD BRAKING

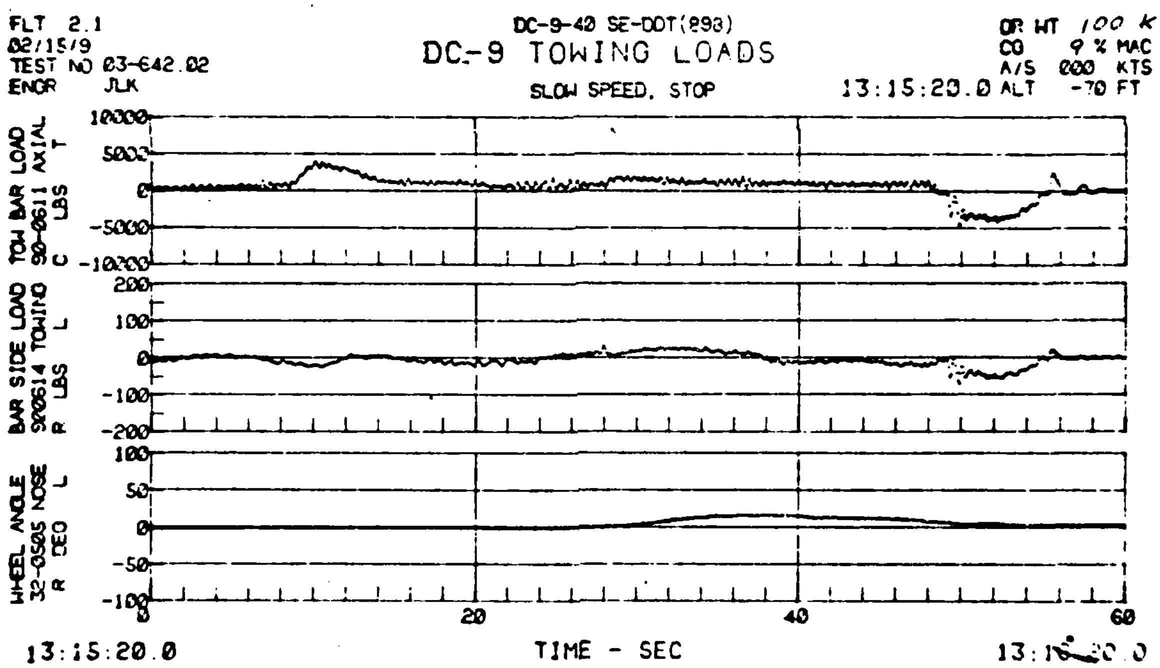


FIGURE B16 FORWARD TOW TO SLOW SPEED THEN TO SLOW STOP

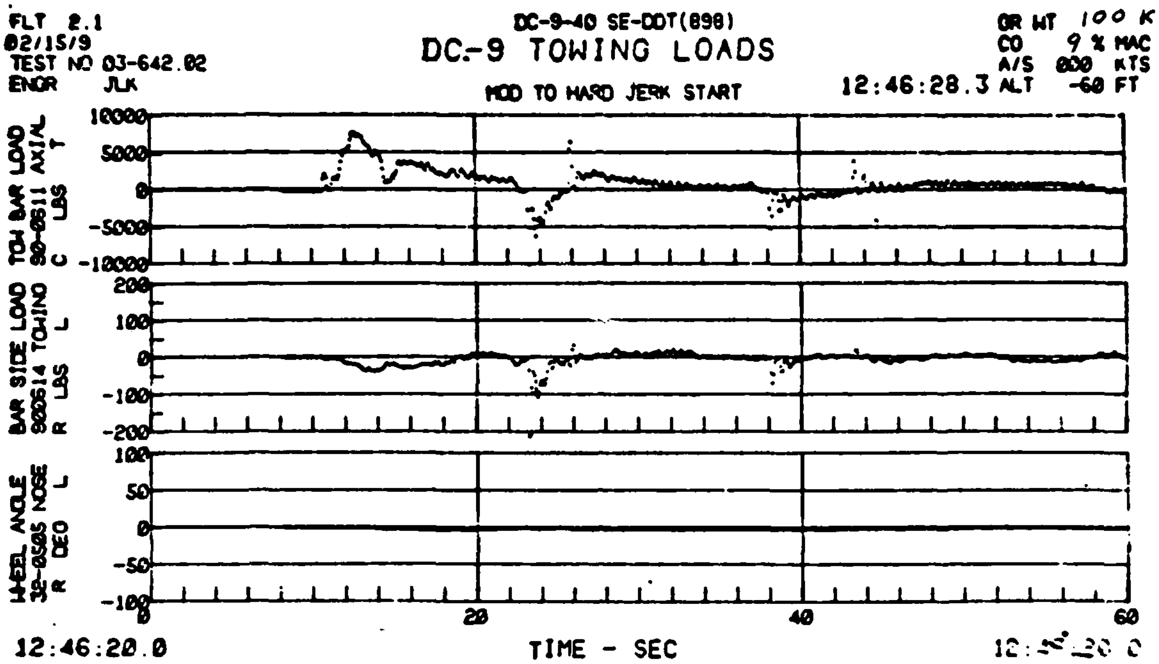


FIGURE B17 - MODERATE TO HARD JERK START

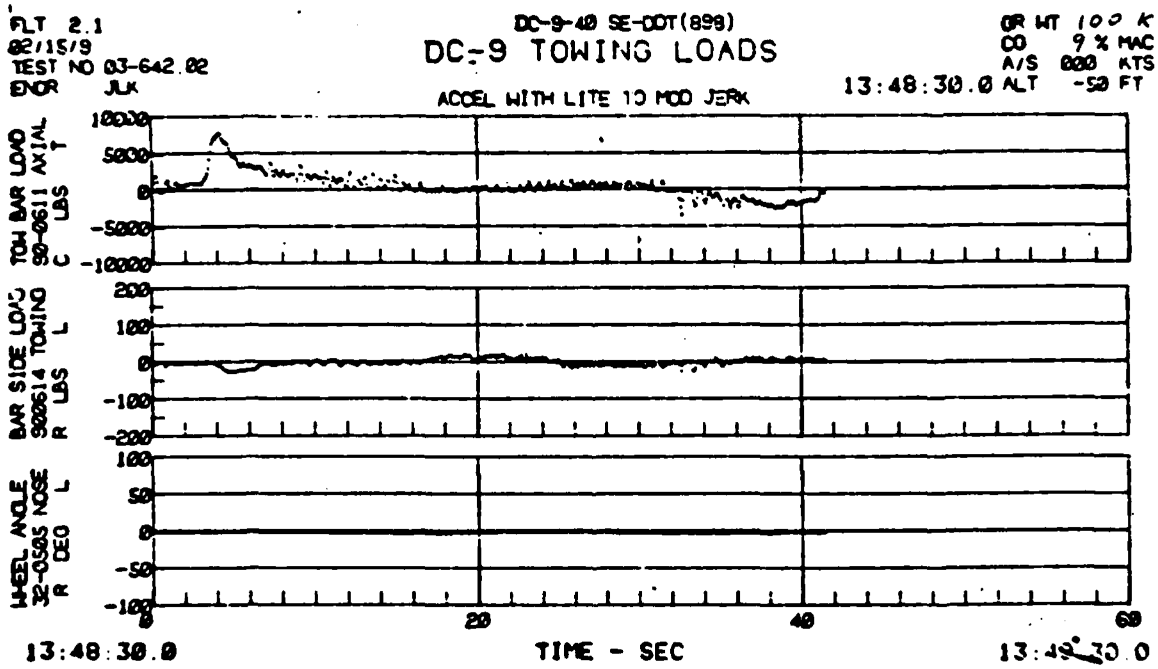


FIGURE B18 - ACCELERATE WITH LIGHT TO MODERATE JERK

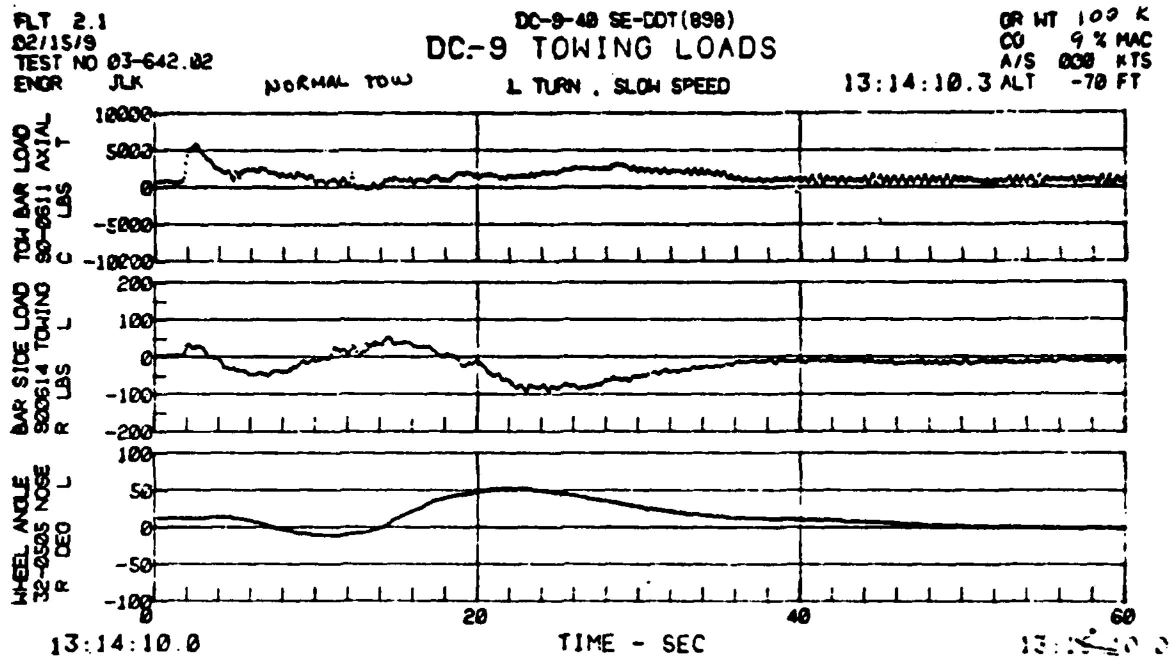


FIGURE B19 - NORMAL FORWARD TOW THEN LEFT TURN

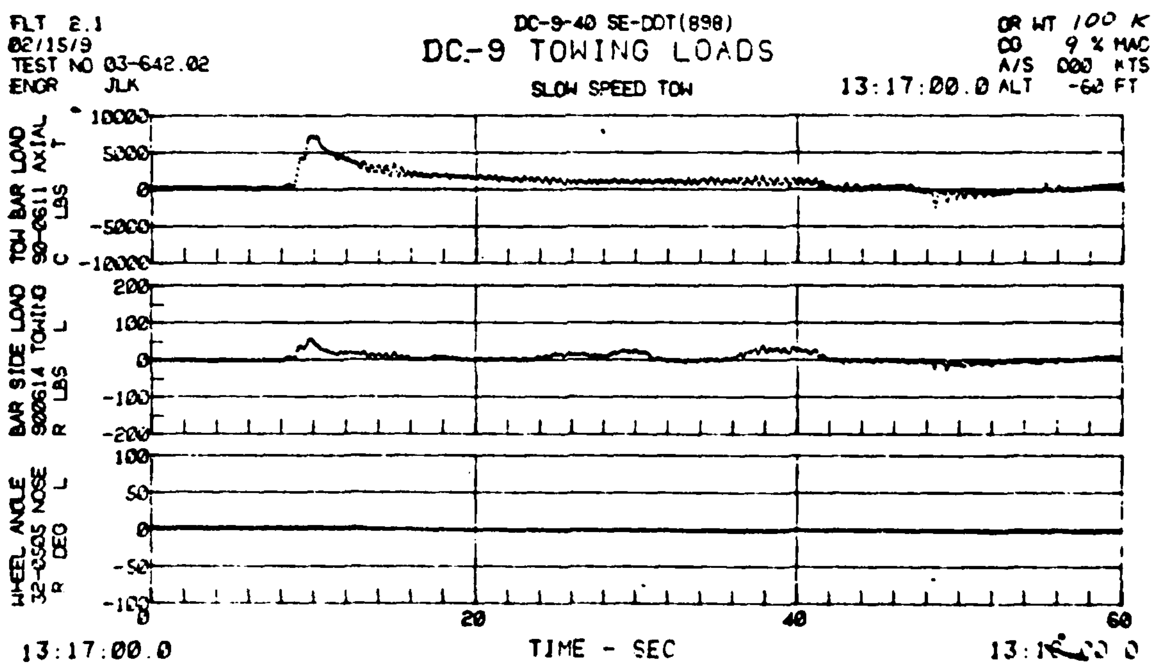


FIGURE B20 - TOW FORWARD AT SLOW SPEED

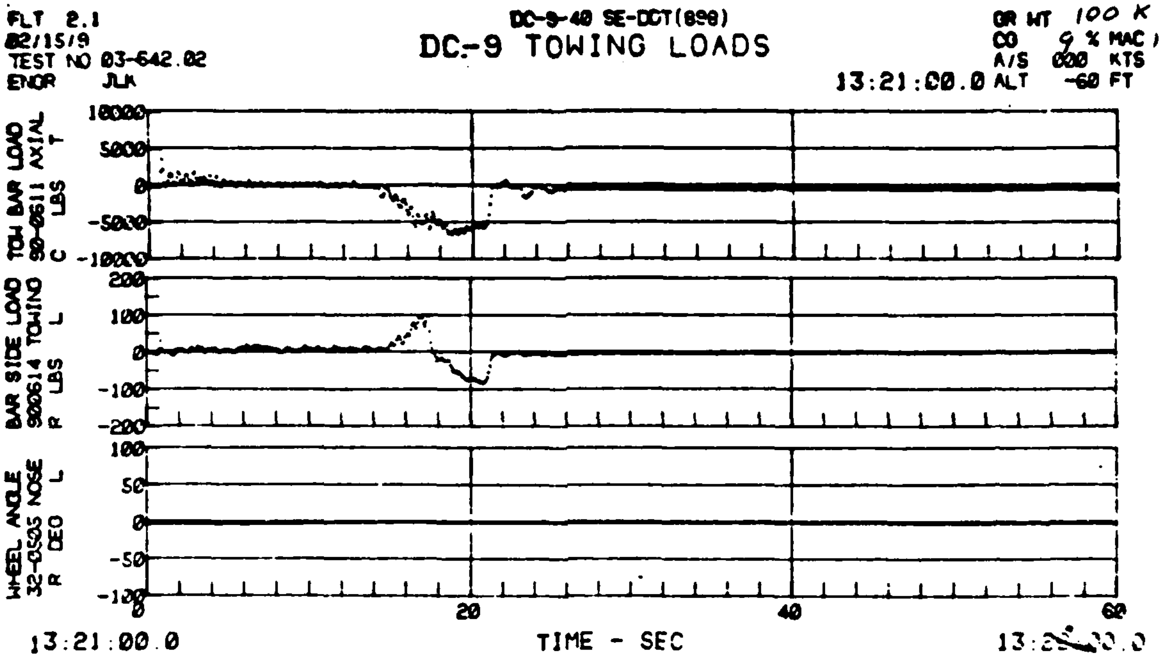


FIGURE B21 - NORMAL STOP FROM 7 KTS.

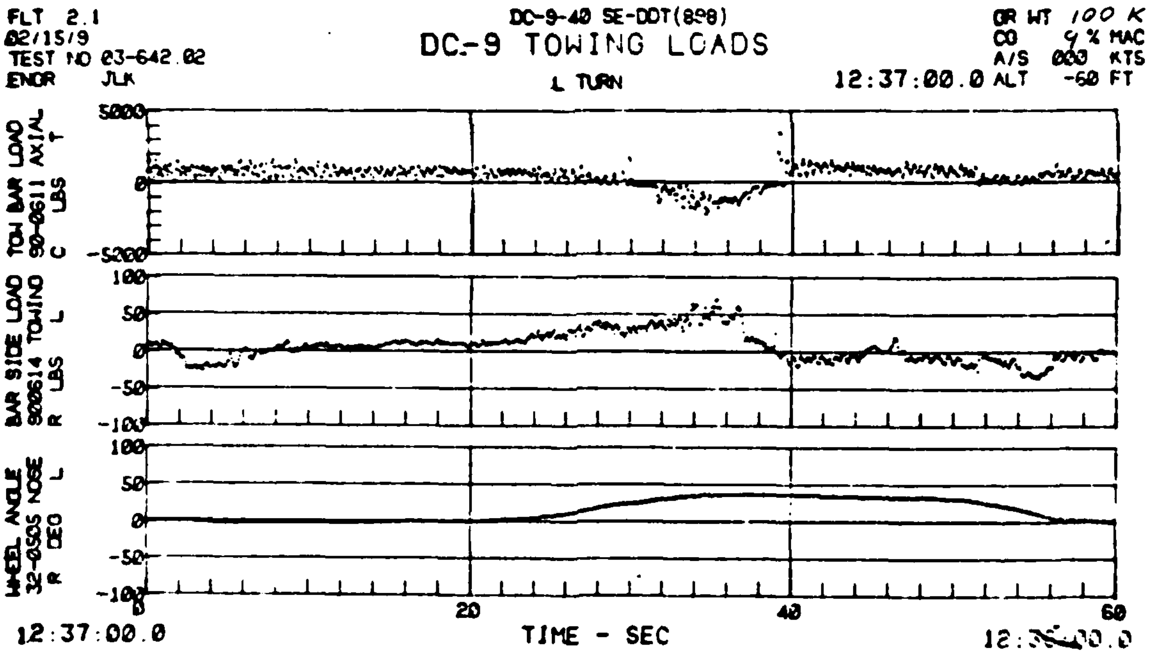


FIGURE B 22 - LEFT TURN

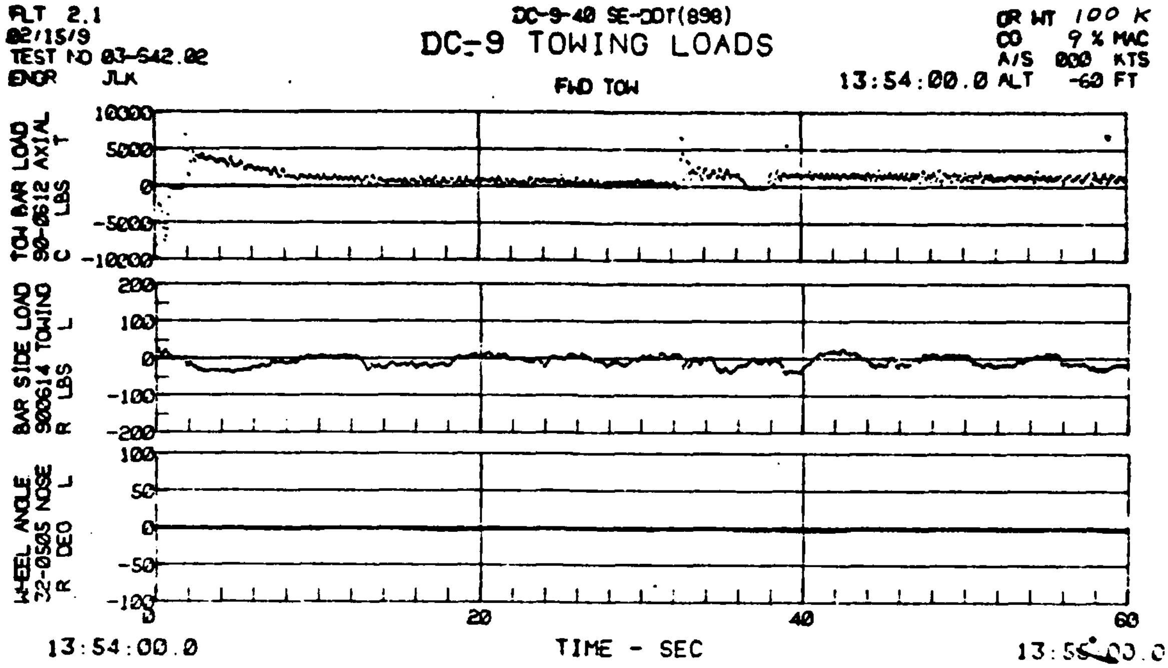


FIGURE B23 - FORWARD TOW, NORMAL ACCELERATE TO 12 KTS.

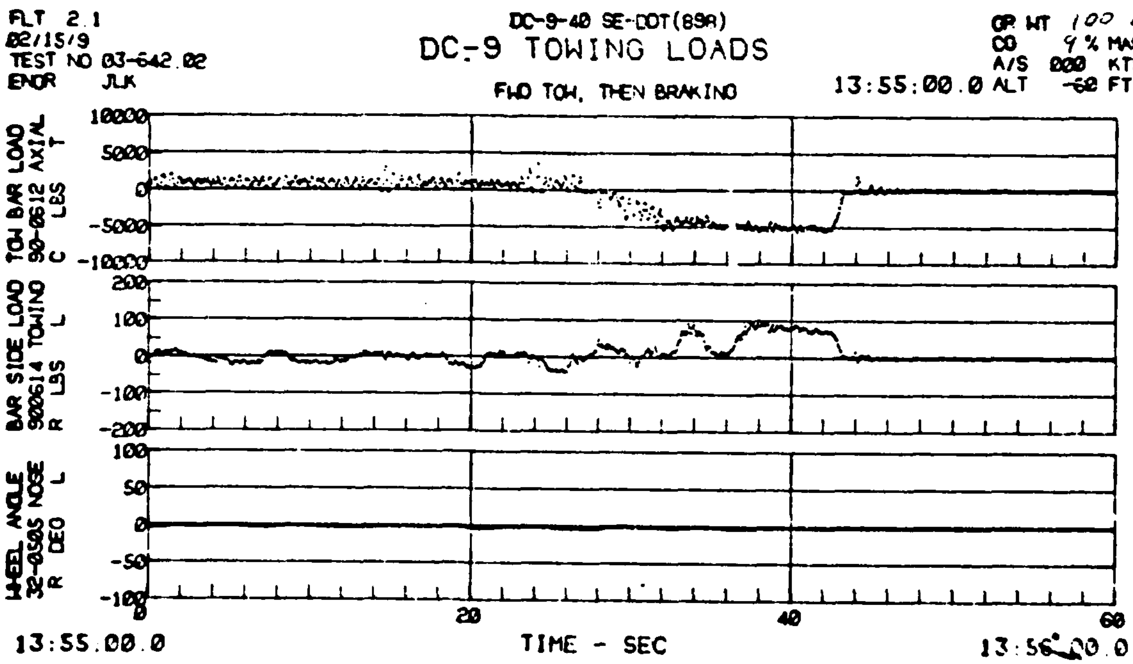


FIGURE B24 - CONTINUATION OF FIGURE B23, STOP WITH LIGHT BRAKING

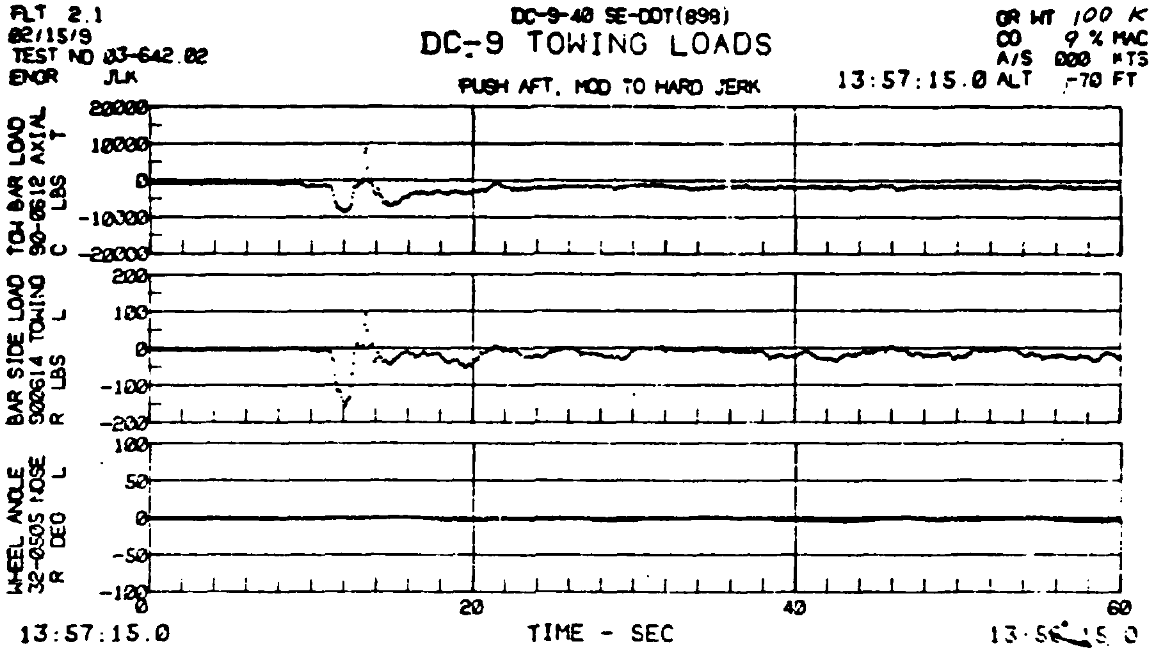


FIGURE B25 - PUSH AFT, MODERATE HARD JERK

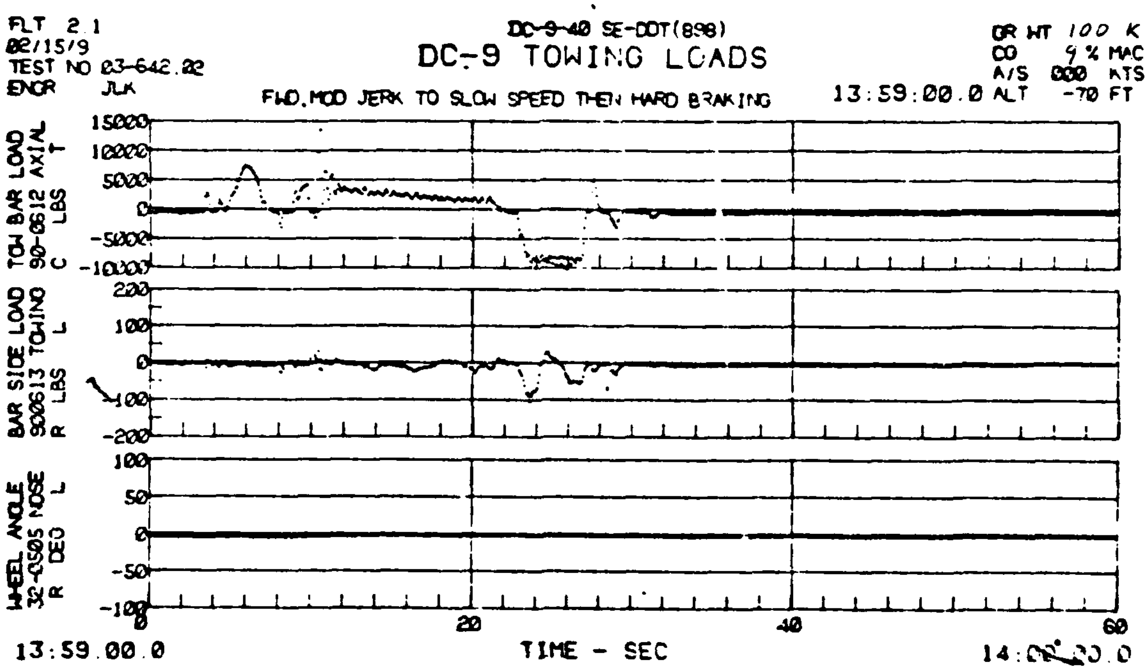


FIGURE B26 - FORWARD TOW MODERATE JERK TO SLOW SPEED THEN HARD BRAKING

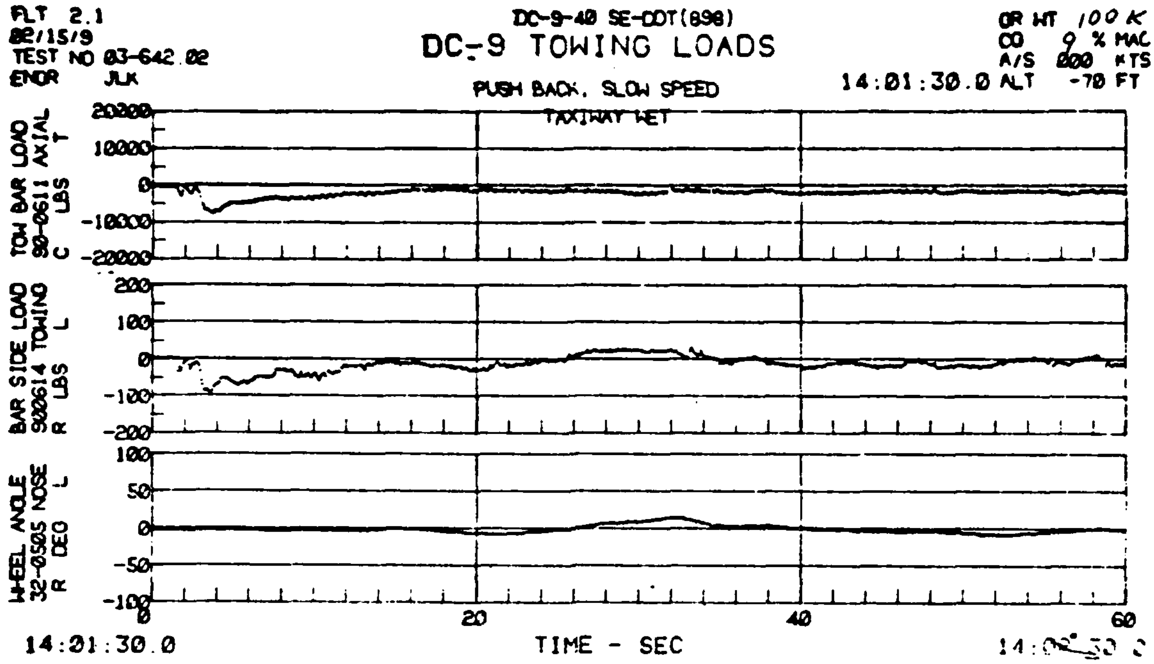


FIGURE B27 - WET TAXIWAY, NORMAL PUSHBACK SLOW SPEED

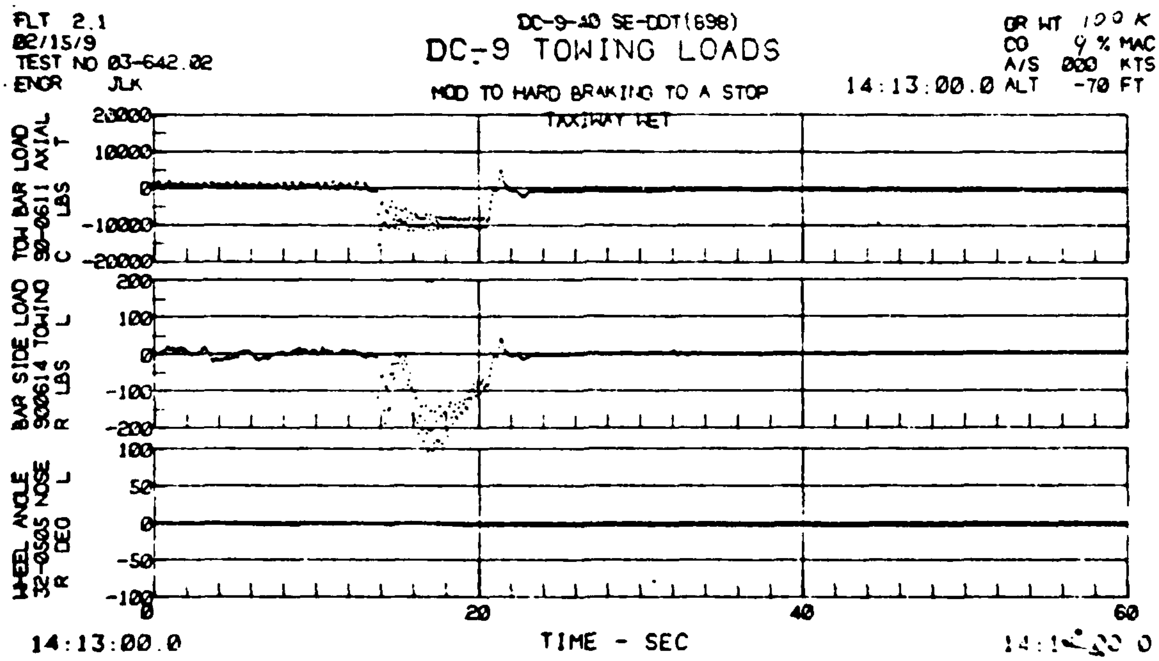


FIGURE B 28 - WET TAXIWAY, MODERATE TO HARD BRAKING TO A STOP FROM 12 KTS.

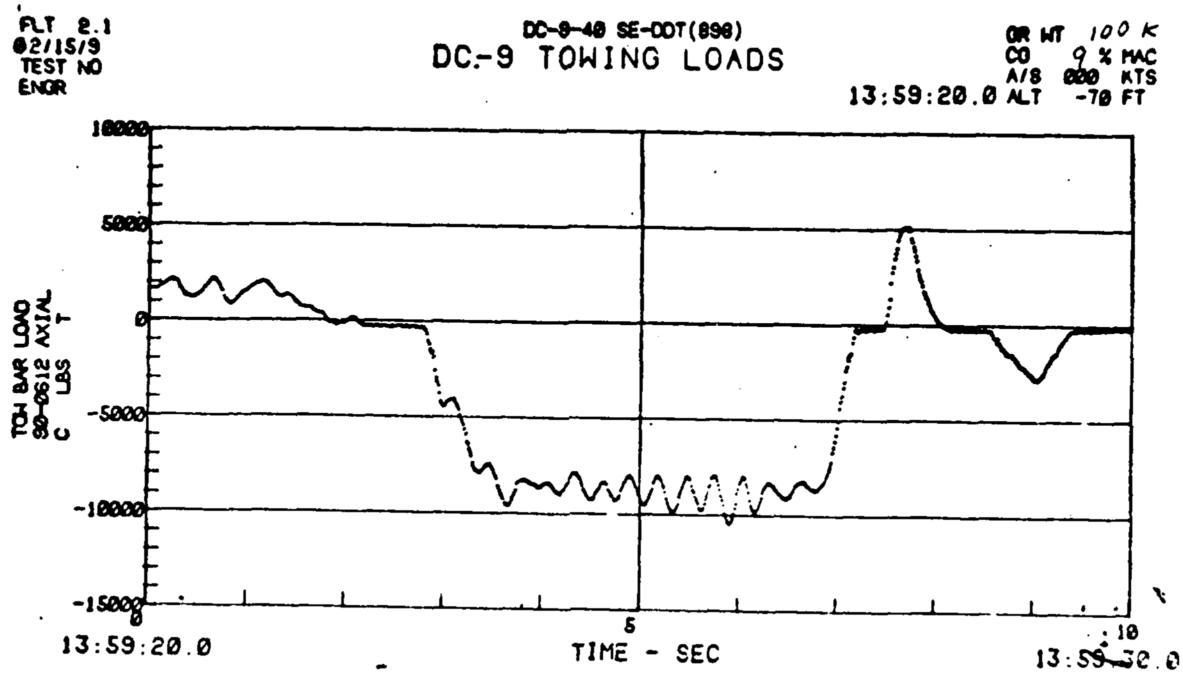


FIGURE B26A - FIGURE B26 WITH EXPANDED TIME SCALE

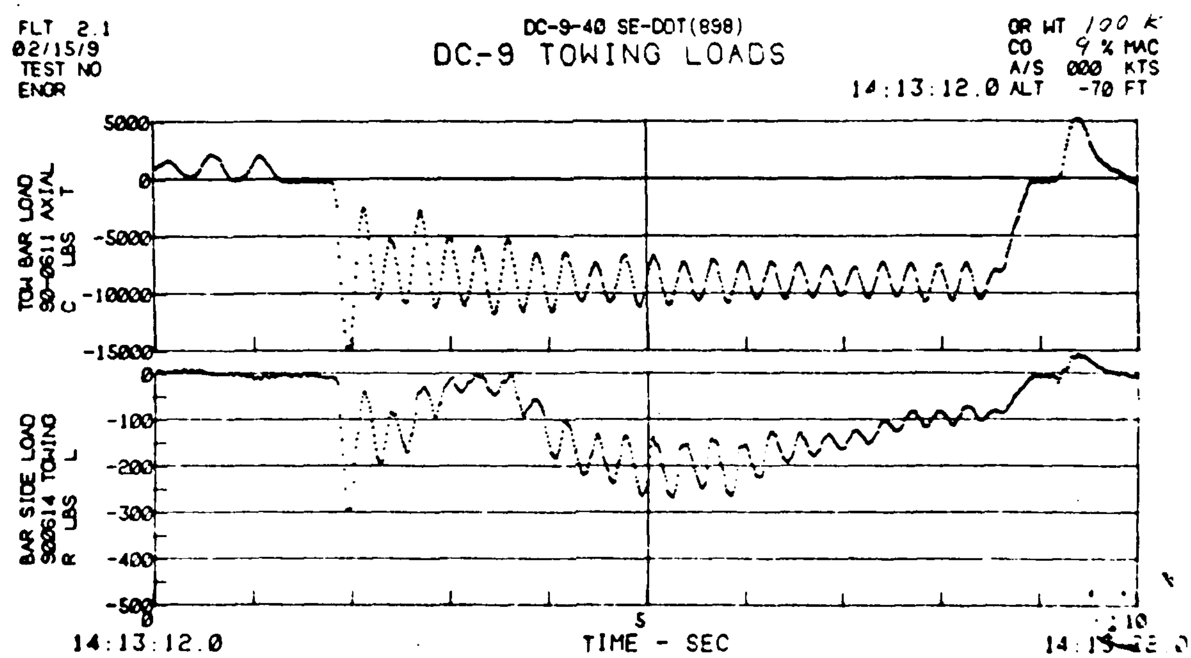


FIGURE 28A - FIGURE B28 WITH EXPANDED TIME SCALE

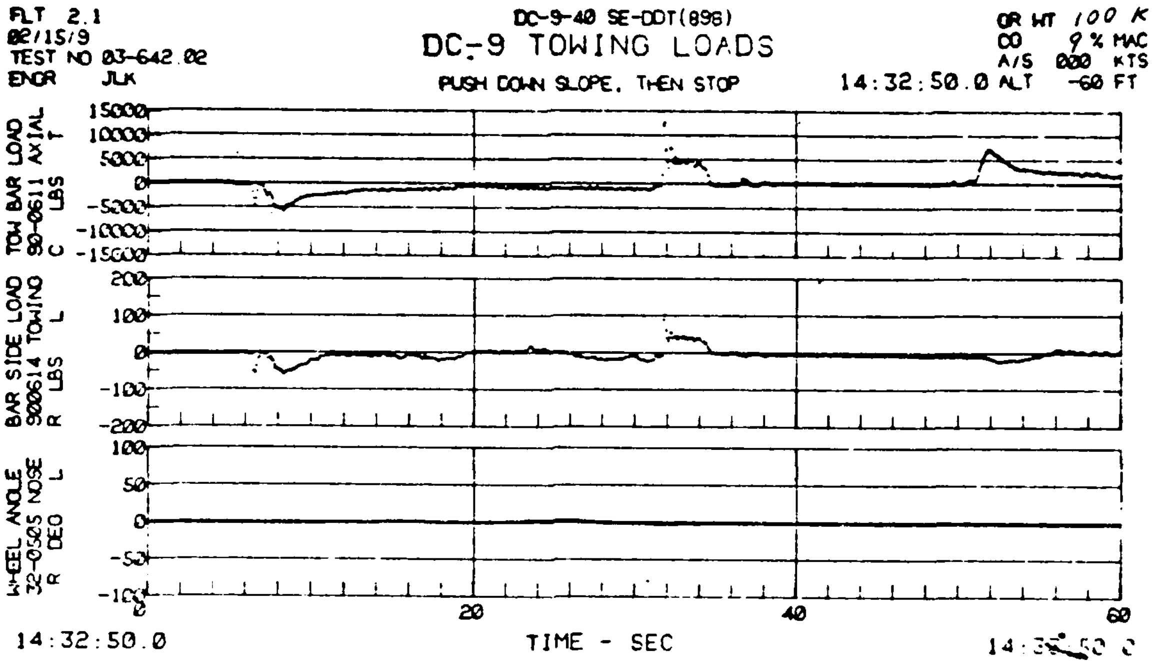


FIGURE B29 - PUSH DOWN SLOPE WITH HARD BRAKING TO STOP, THEN PULL UP SLOPE

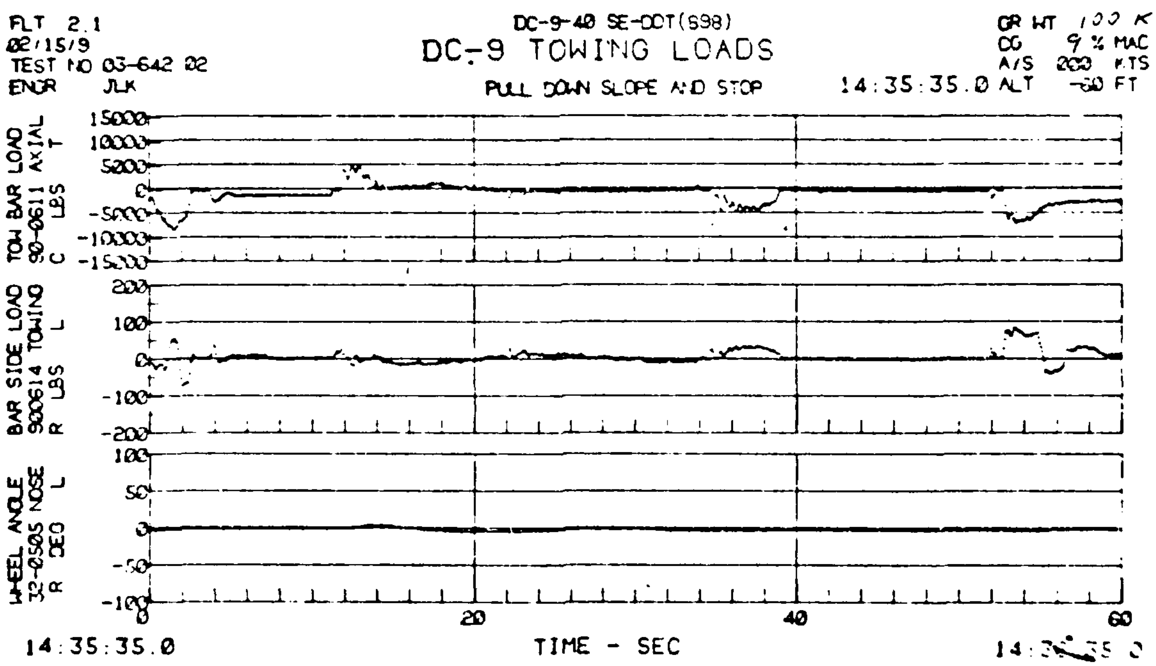


FIGURE B30 - STOP GOING DOWN, PULL DOWN, STOP, PUSH UP

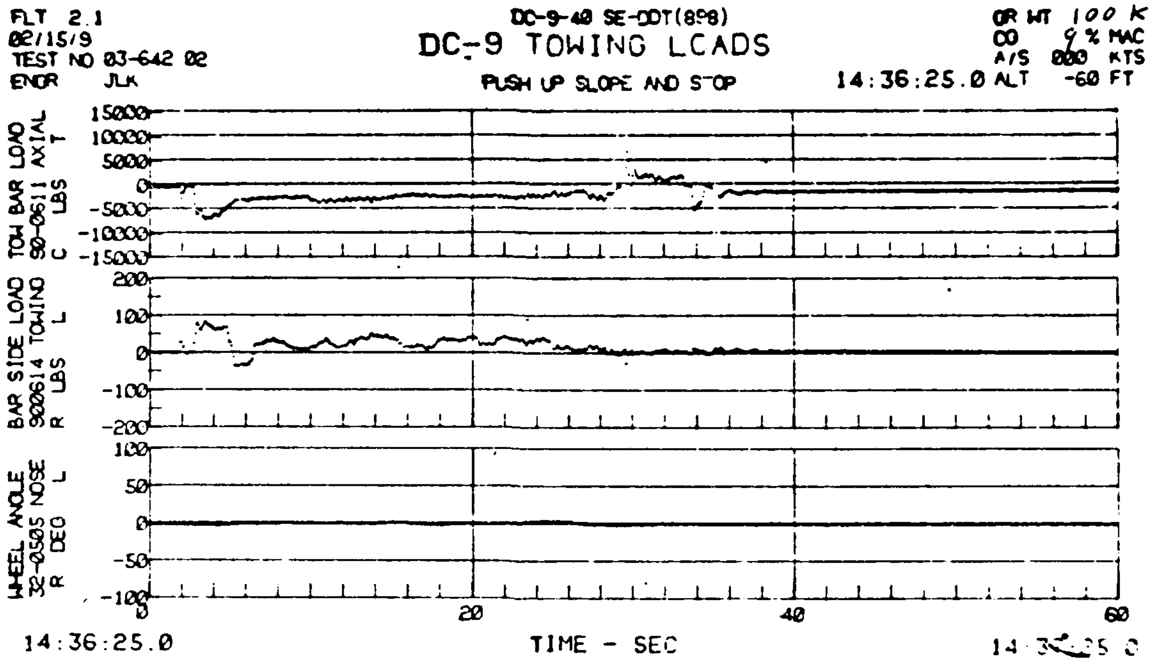


FIGURE B31 - PUSH UP SLOPE AND STOP

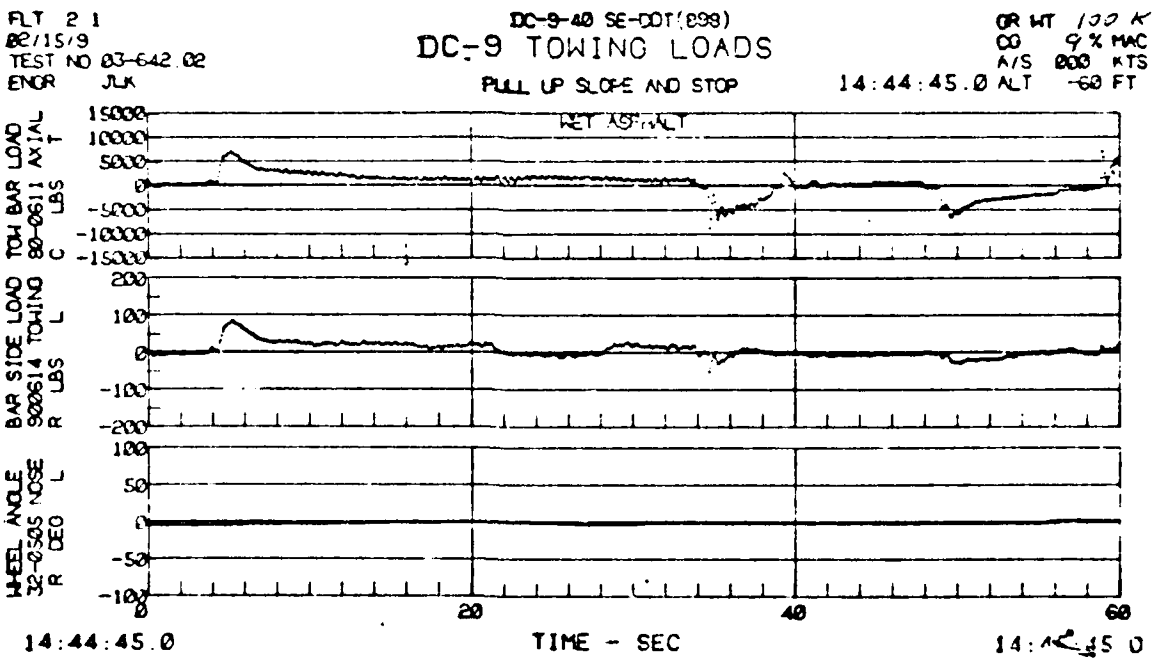


FIGURE B32 - PULL UP SLOPE AND STOP

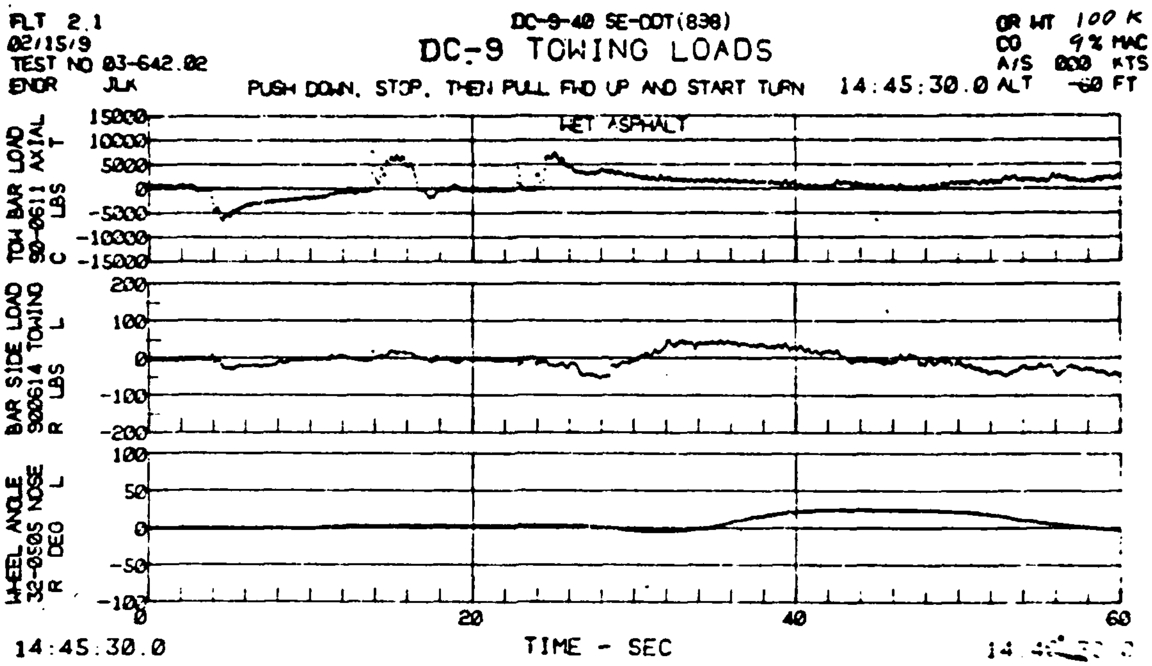


FIGURE B33 - PUSH DOWN SLOPE, STOP THEN PULL UP AND START TURN

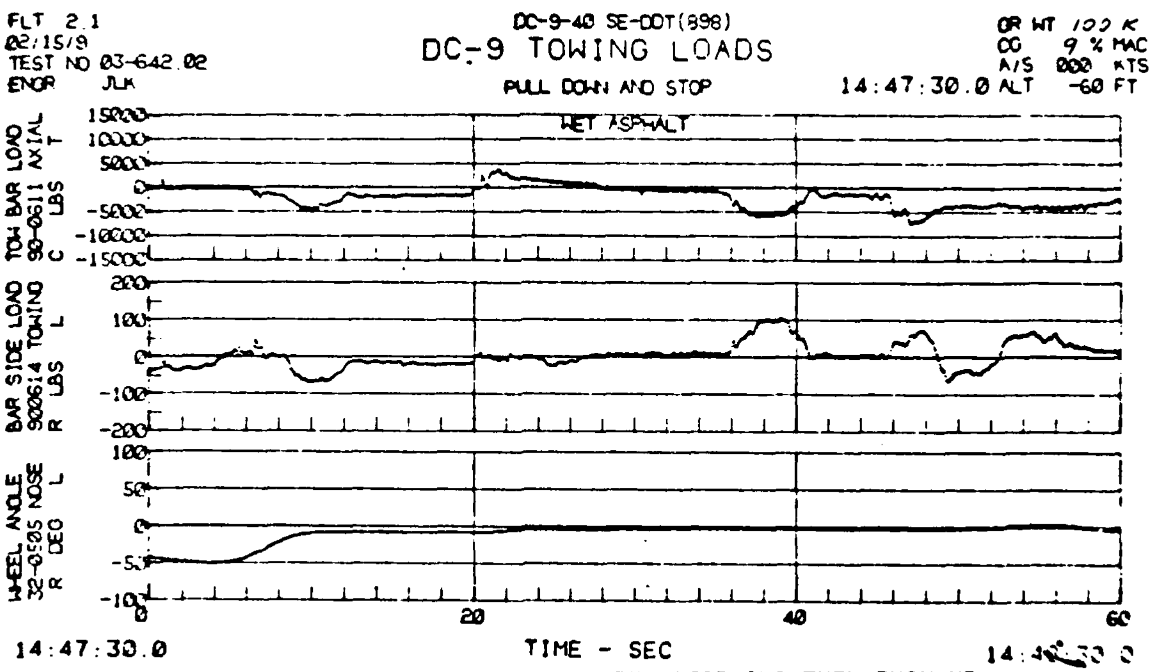


FIGURE B34 - PULL DOWN SLOPE, STOP AND THEN PUSH UP

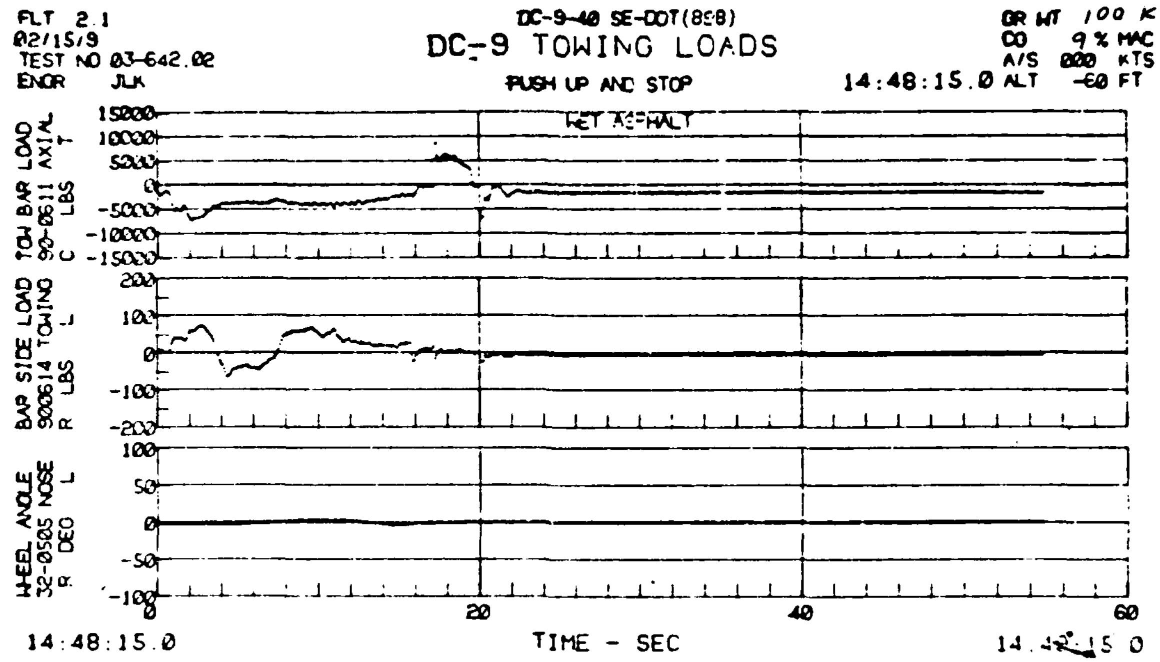


FIGURE B 35 - PUSH UP AND STOP

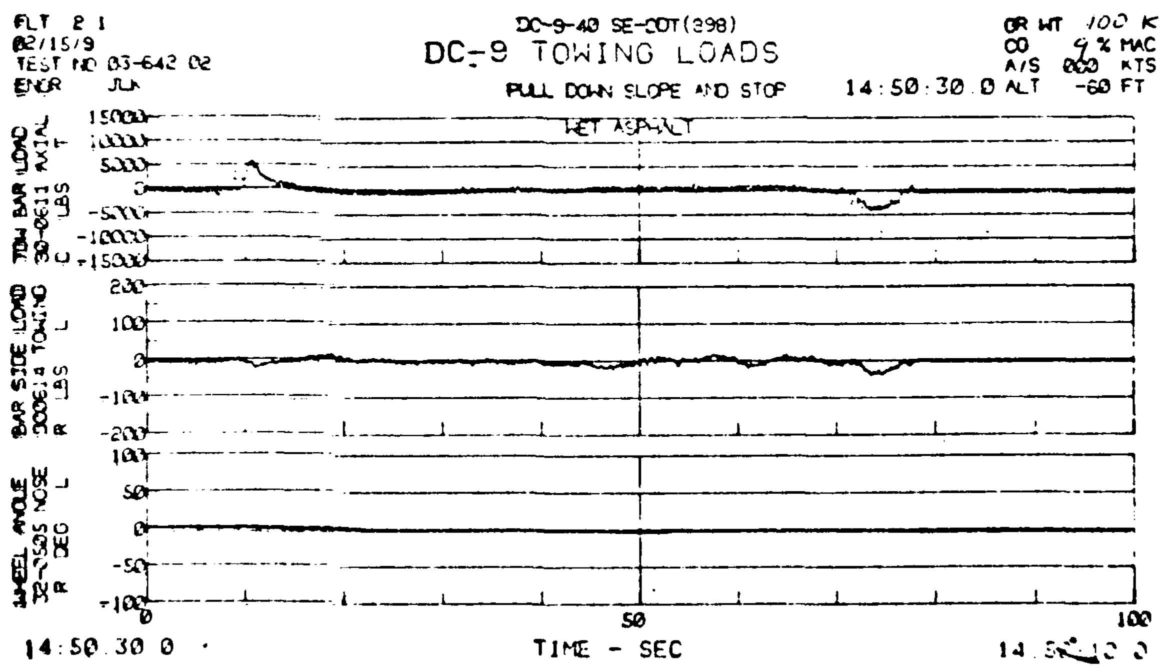


FIGURE B 36 - PULL DOWN SLOPE AND STOP

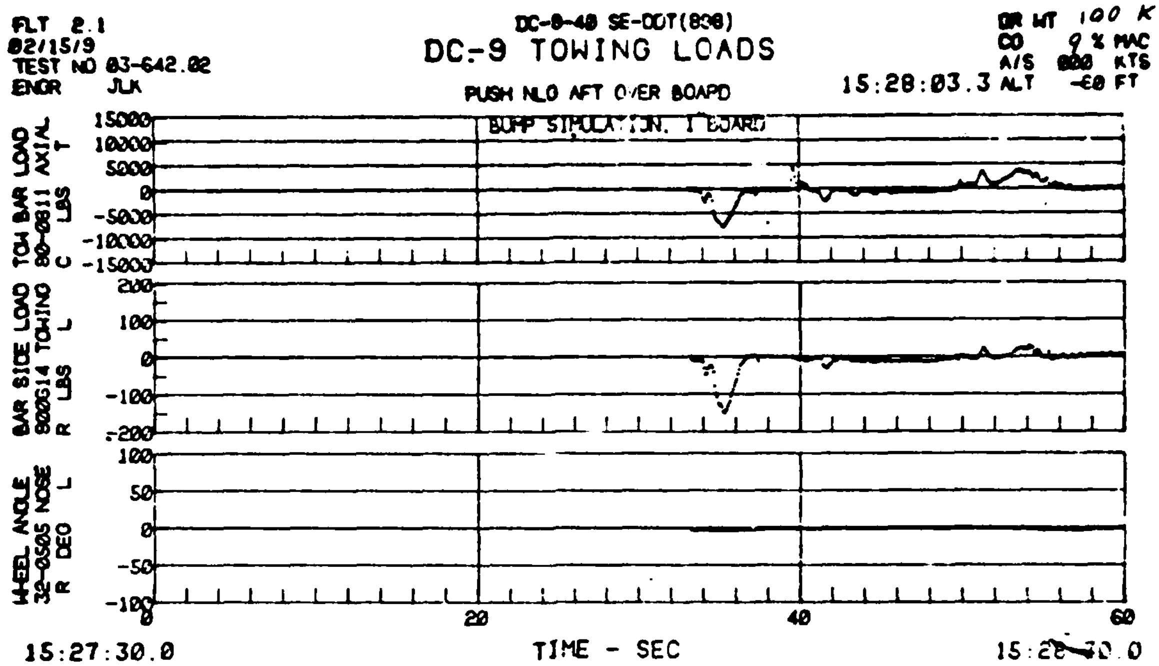


FIGURE B 37 - PUSH AFT, NOSE GEAR OVER BOARD THEN PULL FORWARD

NOSE GEAR OVER BOARD

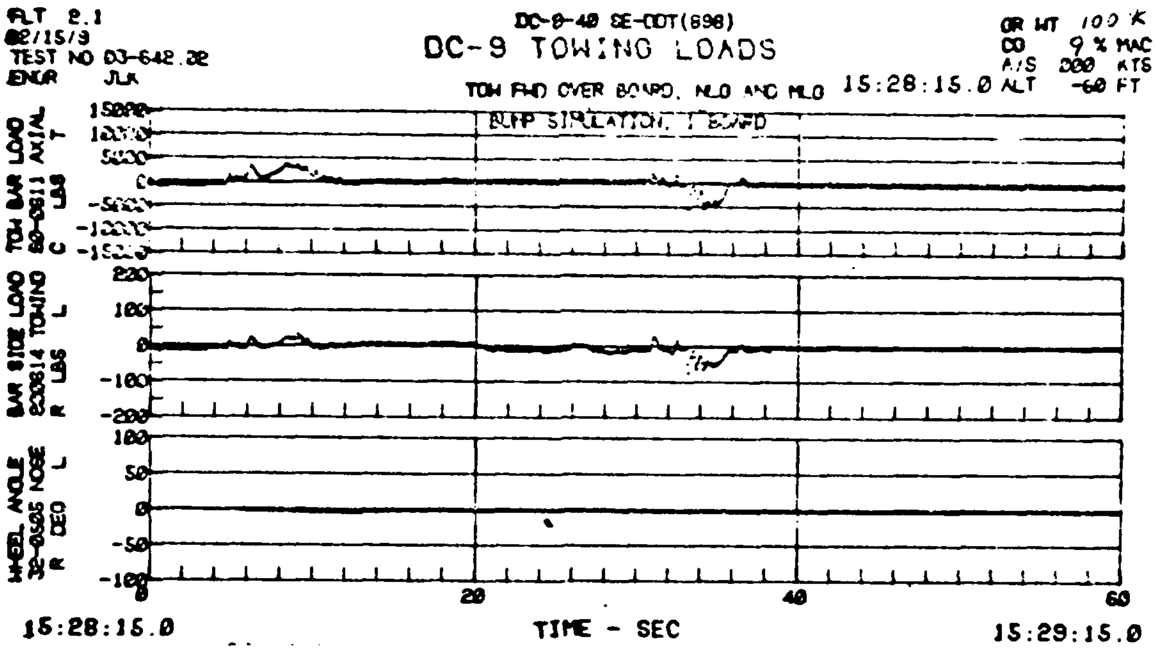


FIGURE B 38 - PULL FORWARD OVER BOARD BOTH NOSE AND MAIN GEAR AT SLOW SPEED

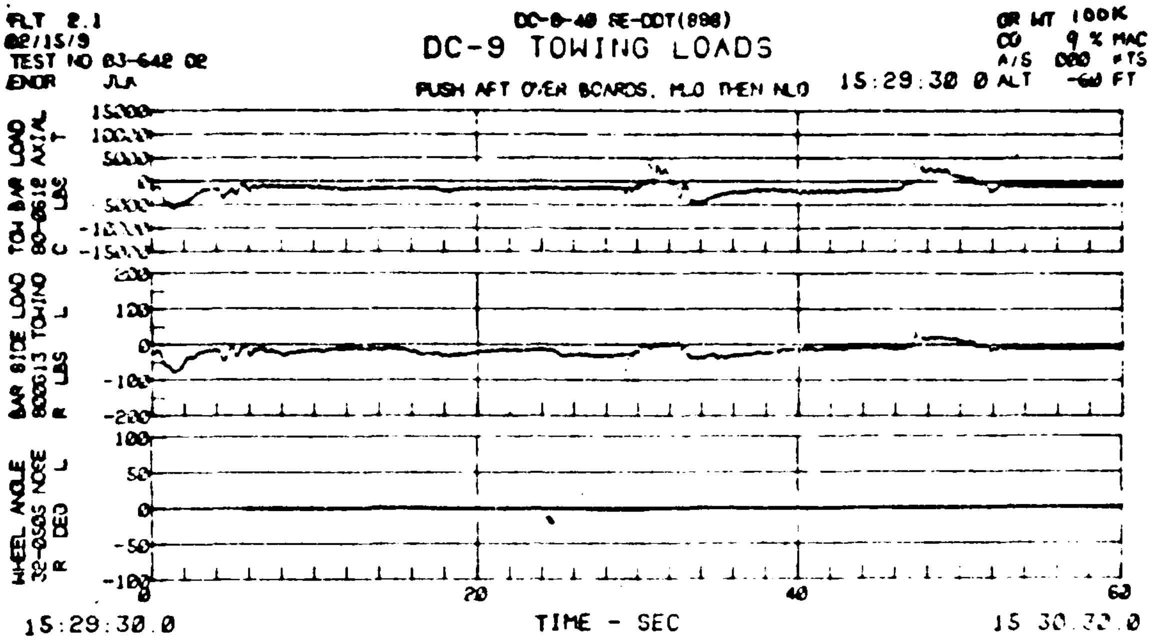


FIGURE B 39 - PUSH AFT MAIN GEAR OVER BOARD THEN SLOW SPEED UNTIL NOSE GEAR PASSES BOARD

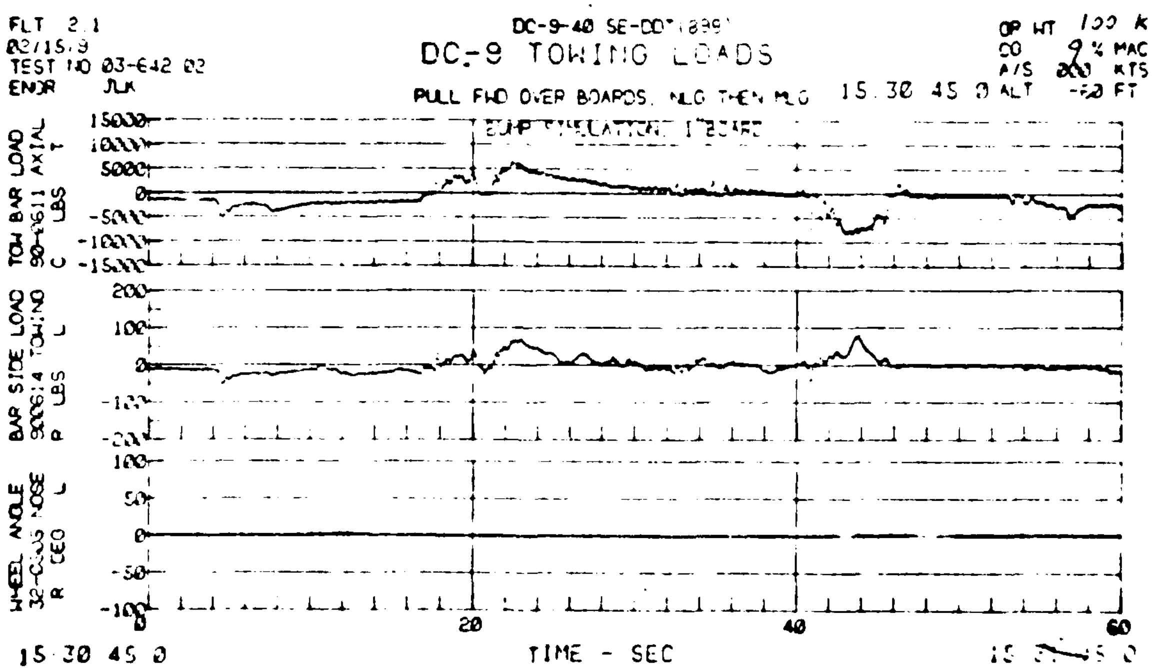


FIGURE B 40 - PULL FORWARD OVER BOARDS AT MODERATE SPEED THEN STOP

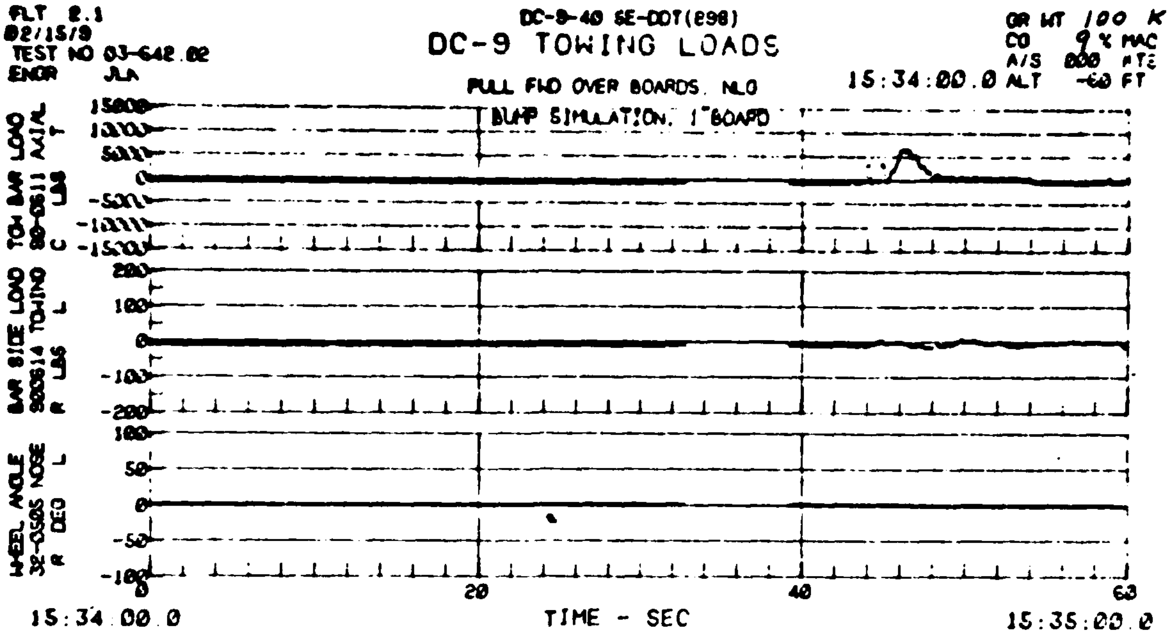


FIGURE B41 - PULL FORWARD NOSE GEAR OVER BOARD

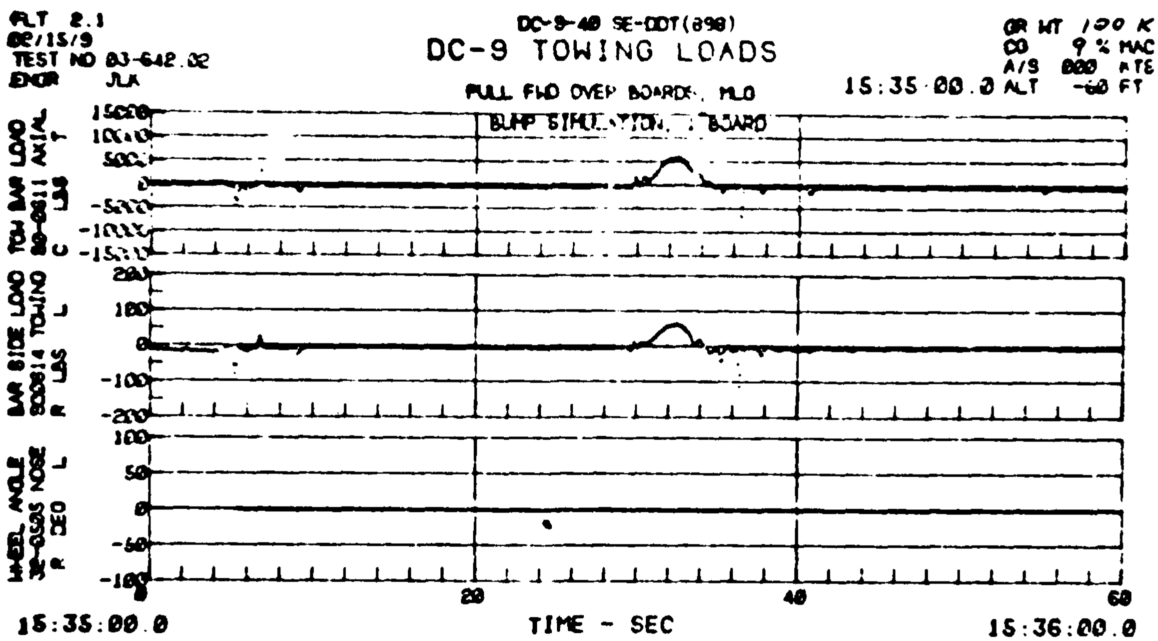


FIGURE B 42 - PULL FORWARD MAIN GEAR OVER BOARD massport

LOGAN INTERNATIONAL AIRPORT, EAST BOSTON, MASS. 02128 (617) 482-2930

November 30, 1978

Mr. E. A. Hoover
Douglas Aircraft Company
Internal Mail Code 35-41
3855 Lakewood Boulevard
Long Beach, CA 90846

Dear Mr. Hoover:

Per your request regarding weather related data for Logan International Airport, I have attached a copy of the 1977 Annual Summary of Climatological Data.

In addition, we have researched our snow removal records and find that the average number of days per year with snow fall of one inch or more is 11 days. We have estimated that the number of days per year with snow fall of one half inch or more would be approximately 30 percent greater or 14 1/2 days. We have also found that the average number of days per year that Logan Airport was closed due to weather is four days.

If I can be of further assistance, do not hesitate to contact me.

Sincerely,

MASSACHUSETTS PORT AUTHORITY

Hubert W. Gainer
Manager of Airports

HWG/kvw

Attachment

Local Climatological Data

Annual Summary With Comparative Data

1977

BOSTON, MASSACHUSETTS

Narrative Climatological Summary

Climate is the composite of numerous weather elements. Three important influences are responsible for the main features of Boston's climate. First, the latitude (42° N) places the city in the zone of prevailing west to east atmospheric flow in which are encompassed the northward and southward movements of large bodies of air from tropical and polar regions. This results in variety and changeability of the weather elements. Secondly, Boston is situated on or near several tracks frequently followed by systems of low air pressure. The consequent fluctuations from fair to cloudy or stormy conditions reinforce the influence of the first factor, while also assuring a rather dependable precipitation supply. The third factor, Boston's east-coast location, is a moderating factor affecting temperature extremes of winter and summer.

Hot summer afternoons are frequently relieved by the locally celebrated "sea-breeze," as air flows inland from the cool water surface to displace the warm westerly current. This refreshing east wind is more commonly experienced along the shore than in the interior of the city or the western suburbs. In winter, under appropriate conditions, the severity of cold waves is reduced by the nearness of the then relatively warm water. The average date of the last occurrence of freezing temperature in spring is April 8; the latest is May 3, 1874 and 1882. The average date of the first occurrence of freezing temperature in autumn is November 7; the earliest on record is October 5, 1881. In suburban areas, especially away from the coast, these dates are later in spring and earlier in autumn by up to one month in the more susceptible localities.

Boston has no dry season. For most years the longest run of days with no measurable precipitation does not extend much more than two weeks. This may occur at any time of year. Most growing seasons have several shorter dry spells during which irrigation for high-value crops may be useful.

Much of the rainfall from June to September comes from showers and thunderstorms. During the rest of the year, low pressure systems pass more or less regularly and produce precipitation on an average of roughly one day in three. Coastal storms, or "northeasters," are prolific producers of rain and snow. The main snow season extends from December through March. The average number of days with four inches or more of snowfall is four per season, and days with seven inches or more come about twice per season. Periods when the ground is bare or nearly bare of snow may occur at any time in the winter.

Relative humidity has been known to fall as low as 5% (May 10, 1962), but such desert dryness is very rare. Heavy fog occurs on an average of about two days per month with its prevalence increasing eastward from the interior of Boston Bay to the open waters beyond.

The greatest number of hours of sunshine recorded in any month was 390, or 86% of possible, in June 1912, while the least was 60 hours, or 21%, in December 1972.

Although winds of 32 m.p.h. or higher may be expected on at least one day in every month of the year, gales are both more common and more severe in winter.

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA SERVICE / NATIONAL CLIMATIC CENTER ASHEVILLE, N.C.

Meteorological Data For The Current Year

Station: BOSTON, MASSACHUSETTS # 14739 GEN LOGAN INTERNATIONAL AP Standard time used: EASTERN Latitude 42° 22' N Longitude 71° 02' W Elevation (ground): 15 feet Year 1977

Month	Temperature °F Averages: Daily maximum	Daily minimum	Monthly	Extremes: Highest	Date	Lowest	Date	Degree days Base 65 °F: Heating	Cooling	Precipitation in inches Water equivalent: Total	Greatest in 24 hrs.	Date	Snow, Ice pellets: Total	Greatest in 24 hrs.	Date	Relative humidity pct. Hour 01	Hour 07	Hour 13	Hour 19 (Local time)
JAN	29.8	16.7	23.3	67	10	3	18	1290	0	4.41	1.74	10-11	23.2	13.8	7	61	63	55	56
FEB	36.6	24.8	30.7	48	25	9	17	956	0	2.40	1.05	24-25	9.9	3.8	20-21	60	61	56	56
MAR	52.9	36.8	44.7	81	30	27	2	625	1	4.78	1.80	22-23	10.7	9.6	18-19	69	69	59	61
APR	61.2	41.4	51.3	88	23	26	9	414	18	4.07	1.55	23-24	T	T	8	67	67	50	57
MAY	73.0	52.2	62.6	92	17	35	10	158	92	3.52	3.09	9-10	0.5	0.5	10	65	63	51	57
JUN	75.8	58.0	67.4	90	28	50	8	43	124	2.49	0.94	10-11	0.0	0.0		82	77	63	72
JUL	84.1	65.7	74.9	102	21	57	27	0	314	2.21	1.19	25	0.0	0.0		74	70	52	62
AUG	82.9	64.5	73.6	95	29	56	26	4	272	2.91	0.71	1-2	0.0	0.0		86	81	63	77
SEP	71.1	57.7	64.4	92	2	47	22	89	75	4.03	1.55	20-21	0.0	0.0		86	86	70	80
OCT	62.1	48.5	55.3	77	2	37	24	304	6	4.63	1.10	1-2	0.0	0.0		80	81	65	75
NOV	53.6	42.6	48.1	67	16	29	28	498	0	2.54	1.45	8-9	0.7	0.7	28	77	80	69	73
DEC	40.7	27.7	34.2	55	21	5	12	948	0	6.20	1.52	21-28	5.2	1.8	5-6	76	79	65	70
YEAR	60.2	44.8	52.5	102	JUL 21	3	JAN 18	5329	897	44.17	3.09	MAY 9-10	44.2	13.8	JAN 7	74	73	60	66

Month	Wind Resultant: Direction	Speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Date	Percent of possible sunshine	Average sky cover tenths, sunrise to sunset	Number of days Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperature °F Maximum (b) 90° and above	32° and below	Minimum 32° and below	0° and below	Average station pressure mb Elev. 29 feet m.s.l.
JAN	28	9.4	14.1	39	W	11	67	5.1	14	7	10	11	4	1	1	0	17	31	0	1007.9
FEB	28	7.1	13.1	38	W	25	57	6.0	9	6	13	12	2	0	4	0	7	22	0	1010.8
MAR	30	5.5	13.1	60	NE	22	61	5.9	9	8	14	13	2	2	3	0	0	10	0	1012.2
APR	28	4.3	14.0	39	NW	5	71	4.8	15	6	9	9	0	0	0	0	0	4	0	1015.9
MAY	27	3.6	12.4	44	NE	9	79	5.1	11	10	10	6	0	2	0	2	0	0	0	1013.2
JUN	25	3.0	10.7	35	SW	17	67	6.9	3	12	15	10	0	4	1	1	0	0	0	1010.2
JUL	26	4.9	10.6	46	N	18	77	5.1	14	8	9	7	0	4	1	9	0	0	0	1015.2
AUG	26	4.5	9.4	38	SW	5	68	6.4	6	12	13	12	0	4	3	5	0	0	0	1016.3
SEP	27	0.5	10.1	38	SW	26	53	6.1	8	10	12	13	0	1	1	1	0	0	0	1015.9
OCT	28	3.0	11.3	36	NE	14	52	6.1	9	8	14	12	0	1	2	0	0	0	0	1014.9
NOV	27	1.9	12.0	37	W	27	30	7.7	5	4	21	10	0	3	3	0	0	3	0	1019.3
DEC	30	5.4	14.2	39	NE	6	46	5.8	12	4	15	16	3	0	3	0	8	19	0	1014.6
YEAR	28	4.2	12.1	60	NE	MAR 22	62	5.9	115	95	155	131	11	22	22	18	32	89	0	1013.0

Normals, Means, And Extremes

Month	Temperatures °F Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity pct. Hour 01	Hour 07	Hour 13	Hour 19 (Local time)
(a)				26		26					26		26		26		42		42		13	13	13	13
J	35.9	22.5	29.2	63	1974	-12	1957	1110	0	3.69	9.54	1958	0.89	1970	2.07	1958	32.5	1948	13.8	1977	65	66	57	61
F	37.5	23.3	30.4	68	1957	-4	1961	969	0	3.54	7.08	1969	1.13	1968	2.68	1969	41.3	1969	19.4	1958	64	67	57	60
M	44.6	31.5	38.1	81	1977	6	1967	834	0	4.01	11.00	1953	1.48	1962	4.13	1968	31.2	1956	17.7	1960	67	68	57	62
A	56.3	40.8	48.6	94	1976	17	1954	492	0	3.49	7.82	1958	1.24	1966	2.31	1973	3.3	1967	3.1	1956	67	66	53	59
M	67.1	50.1	58.6	93	1964	34	1956	218	20	3.47	13.38	1954	0.53	1964	5.74	1954	0.5	1977	0.5	1977	72	70	57	64
J	76.6	59.3	68.0	100	1952	46	1965	27	117	3.19	8.03	1959	0.48	1953	2.46	1960	0.0		0.0		78	74	60	68
J	81.4	65.1	73.3	102	1977	54	1965	0	260	2.74	8.12	1959	0.52	1952	2.42	1959	0.0		0.0		76	73	56	66
A	79.3	63.3	71.3	102	1975	47	1965	8	203	3.46	17.09	1955	0.83	1972	8.40	1955	0.0		0.0		78	75	57	68
S	72.2	56.7	64.5	100	1953	38	1965	76	61	3.16	8.31	1954	0.35	1957	5.64	1954	0.0		0.0		80	79	61	72
O	63.2	47.5	55.4	90	1963	28	1976	301	0	3.02	8.08	1962	0.96	1967	4.26	1962	T	1975	T	1975	75	76	57	67
N	51.7	38.7	45.2	77	1974	17	1972	594	0	4.51	8.10	1969	0.64	1976	3.33	1955	10.0	1938	8.0	1940	72	74	61	67
D	39.3	26.6	33.0	70	1960	-4	1962	992	0	4.24	9.74	1969	1.03	1955	4.17	1969	27.9	1970	13.0	1960	69	72	61	66
YR	58.7	43.8	51.3	102	JUL 1977	-12	JAN 1957	5621	661	42.52	17.09	AUG 1955	0.35	SEP 1957	8.40	AUG 1955	41.3	FEB 1969	19.4	FEB 1958	72	72	58	65

Month	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F Max. (b) 90° and above	32° and below	Min. 32° and below	0° and below	Average station pressure mb Elev. 29 feet m.s.l.
(a)	20	15	19	19		42	42	42	42	42	26	42	42	42	13	13	13	13	5
J	14.2	NW	61	NW	1976	56	6.2	9	7	15	12	3	*	2	0	11	26	1	1014.8
F	14.1	WNW	57	S	1970	56	6.2	8	7	13	11	3	*	2	0	8	24	*	1014.0
M	14.0	NW	60	NE	1977	57	6.4	8	8	15	12	2	1	2	0	2	17	0	1013.9
A	13.4	WNW	52	NW	1963	57	6.4	7	9	14	11	*	1	2	*	0	3	0	1012.4
M	12.2	SW	50	NE	1967	59	6.5	6	11	14	11	0	2	3	*	0	0	0	1013.1
J	11.3	SW	60	NW	1959	63	6.3	7	10	13	11	0	4	2	3	0	0	0	1014.1
J	10.8	SW	46	N	1977	66	6.1	7	12	12	9	0	5	2	5	0	0	0	1013.7
A	10.8	SW	65	SW	1971	67	5.6	9	11	11	10	0	4	2	3	0	0	0	1016.3
S	11.2	SW	57	S	1960	63	5.5	10	8	12	9	0	2	2	1	0	0	0	1016.5
O	12.1	SW	65	NW	1963	61	5.5	11	8	12	9	0	1	2	0	0	1	0	1017.1
N	13.0	SW	54	NE	1968	51	6.4	8	7	15	11	*	*	2	0	*	6	0	1016.9
D	13.8	WNW	69	NW	1962	52	6.2	9	7	15	12	2	*	1	0	6	21	*	1015.4
YR	12.6	SW	61	NW	JAN 1974	60	6.1	99	105	161	128	11	19	23	12	27	98	1	1014.7

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 104 in July 1911; lowest temperature -18 in February 1934; minimum monthly precipitation T in March 1915; fastest mile wind 87 S in September 1938.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Average Temperature

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1938	28.6	30.4	39.1	48.7	55.6	67.2	71.8	73.4	62.2	56.0	44.4	34.0	51.1
1939	27.8	32.2	33.2	43.6	56.4	65.6	72.3	73.8	64.5	54.2	40.8	33.4	49.8
1940	23.6	29.6	33.1	43.6	56.2	65.1	71.6	68.4	63.3	50.6	42.9	34.3	48.8
1941	25.3	29.4	33.4	51.6	59.8	68.2	71.4	70.6	66.0	55.9	48.0	35.2	51.2
1942	28.6	27.6	40.8	49.7	60.8	67.4	71.1	70.7	64.6	55.8	43.5	28.6	50.7
1943	25.5	30.6	36.0	43.4	57.6	71.2	74.1	71.0	63.0	53.8	43.3	29.6	49.9
1944	31.6	29.8	34.1	44.6	63.2	67.0	73.8	74.7	65.0	53.8	43.2	30.8	50.9
1945	23.8	30.3	46.3	52.5	55.2	66.6	71.9	70.8	67.1	53.1	45.5	28.5	51.0
1946	28.4	27.6	47.2	46.2	58.0	67.5	70.8	67.8	65.8	58.4	47.8	34.8	51.7
1947	32.6	29.6	37.7	47.2	56.9	65.4	74.4	73.2	64.8	61.6	41.2	30.4	51.2
1948	23.4	26.6	38.0	48.0	55.0	63.6	74.5	73.7	65.7	54.2	49.6	36.3	50.7
1949	34.6	34.4	38.2	50.8	60.4	71.6	76.2	74.4	63.2	58.4	43.5	36.0	53.6
1950	36.2	28.0	33.7	46.8	55.8	69.1	73.5	70.9	61.5	56.3	47.8	35.5	51.3
#1951	34.0	34.7	39.1	51.0	59.1	66.0	74.0	70.7	65.4	54.8	42.6	35.0	52.2
1952	32.4	32.5	37.2	50.5	57.2	70.7	77.5	72.3	66.3	53.0	44.9	35.7	52.6
1953	34.7	35.0	39.1	48.9	58.4	70.5	73.2	72.0	66.3	56.2	48.6	40.2	53.6
1954	26.0	36.4	38.6	50.1	56.3	66.6	72.2	70.1	63.2	58.6	44.4	34.4	51.4
1955	28.5	32.0	37.6	49.2	62.8	66.8	77.2	74.5	64.5	55.1	41.9	26.6	51.4
1956	30.6	32.5	33.6	45.6	55.4	68.5	71.7	71.9	61.1	54.4	46.1	36.0	50.7
1957	29.4	34.7	39.1	49.4	59.9	71.3	74.1	69.3	67.3	54.6	47.2	40.0	52.5
1958	31.0	25.5	39.1	48.8	56.6	63.9	72.4	72.4	64.6	52.6	46.6	26.4	50.0
1959	28.7	26.7	37.0	49.0	62.6	64.6	74.7	74.1	68.1	55.1	44.4	36.3	51.8
1960	30.9	35.3	32.7	48.3	59.7	69.6	73.1	72.1	63.7	53.9	48.0	29.5	51.4
1961	25.0	31.6	36.8	45.3	56.3	68.9	72.1	72.5	69.0	57.3	44.6	32.8	51.0
1962	28.7	26.7	38.5	49.4	57.2	68.4	70.4	70.0	62.9	54.1	41.7	30.0	49.8
#1963	29.5	25.9	39.1	48.9	59.4	69.5	74.7	70.4	60.8	60.0	48.3	25.9	51.0
#1964	31.7	29.1	38.7	46.1	60.3	67.1	71.5	66.4	62.0	52.5	44.1	32.4	50.2
1965	25.4	28.0	35.8	44.2	59.5	67.4	71.0	70.5	62.5	52.8	42.1	36.1	49.6
1966	28.8	31.3	39.8	45.9	57.3	69.4	74.9	71.3	63.5	54.5	46.9	34.2	51.5
1967	35.1	26.4	33.2	44.9	51.7	67.2	73.0	70.9	62.7	53.8	40.1	35.0	49.5
1968	25.6	26.1	39.1	49.6	56.1	64.9	75.2	70.7	65.0	57.9	43.8	30.9	50.4
1969	29.3	29.5	35.4	50.0	58.5	69.2	71.0	74.3	63.7	54.3	44.9	33.4	51.2
1970	23.0	32.3	37.4	49.0	59.6	67.0	74.3	73.6	65.6	54.9	44.8	28.9	50.9
1971	23.8	30.5	36.7	45.1	55.7	69.1	73.4	73.4	68.0	59.6	43.1	36.3	51.2
1972	33.0	29.6	36.3	44.9	57.6	65.4	73.8	71.5	65.7	51.6	42.3	33.0	50.4
1973	31.4	30.1	43.3	49.9	57.0	70.0	74.3	74.8	64.4	55.6	45.8	39.6	53.0
1974	31.7	29.1	38.7	50.9	56.7	64.8	72.4	72.0	63.7	50.1	45.3	37.8	50.9
1975	34.9	32.1	36.9	45.1	61.5	67.5	75.9	72.9	63.9	57.3	51.8	34.4	52.8
1976	26.1	37.3	41.2	55.1	60.2	73.4	72.9	72.0	64.9	52.3	41.9	29.0	52.2
1977	23.3	30.7	44.7	51.3	62.6	67.4	74.9	73.4	64.4	55.3	48.1	34.2	52.5
RECORD MEAN	28.8	29.2	37.0	47.0	57.8	67.0	72.6	70.8	64.0	54.2	43.5	32.6	50.4
MAX	36.3	36.9	44.5	55.1	66.4	75.8	80.9	78.8	72.0	62.1	50.6	39.6	58.3
MIN	21.2	21.5	29.5	38.9	49.1	58.2	64.2	62.7	56.0	46.2	36.3	25.5	42.6

Heating Degree Days

BOSTON, MA

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
1957-58	0	7	57	317	529	766	1046	1102	796	481	262	85	5448
1958-59	4	2	84	386	547	1190	1118	1065	802	476	142	92	5908
1959-60	1	7	79	319	611	885	1048	855	992	493	166	33	5489
1960-61	0	5	103	339	503	1094	1231	928	865	587	287	22	5960
1961-62	6	3	91	246	604	991	1118	1060	814	467	271	35	5672
1962-63	6	13	105	330	691	1078	1094	1087	798	477	196	38	5913
#1963-64	1	3	160	198	495	1207	1026	1033	808	559	187	57	5734
1964-65	14	26	140	380	620	1004	1220	1032	900	617	195	80	6228
1965-66	2	37	136	371	680	888	1115	936	776	566	258	46	5811
1966-67	0	1	88	322	535	950	921	1075	977	596	403	58	5926
1967-68	0	4	110	347	739	923	1214	1122	797	456	270	76	6056
1968-69	1	9	46	247	630	1050	1099	987	911	430	208	21	5639
1969-70	2	3	107	326	595	973	1295	909	846	473	184	52	5765
1970-71	0	0	68	314	598	1113	1269	962	868	586	287	25	6090
1971-72	0	2	37	169	651	882	985	1021	883	598	290	54	5532
1972-73	3	4	51	405	673	985	1033	971	666	450	258	24	5523
1973-74	0	2	94	289	570	782	1023	1000	809	429	335	77	5410
1974-75	0	2	102	458	587	836	925	918	866	590	162	59	5505
1975-76	0	8	70	239	395	941	1198	800	733	331	166	16	4897
1976-77	1	10	55	393	688	1168	1290	956	623	414	158	43	5739
1977-78	0	4	85	304	498	948							

Cooling Degree Days

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1969	0	0	0	9	13	136	196	297	74	1	0	0	746
1970	0	0	0	0	25	118	294	273	91	9	0	0	810
1971	0	0	0	0	6	155	269	271	132	15	1	0	849
1972	0	0	0	0	26	74	279	213	79	0	0	0	671
1973	0	0	0	7	18	180	296	316	84	3	0	0	904
1974	0	0	0	10	22	81	235	226	68	1	3	0	646
1975	0	0	0	0	60	139	345	261	44	9	4	0	862
1976	0	0	0	43	25	276	251	231	61	8	0	0	895
1977	0	0	1	13	92	124	314	272	75	6	0	0	897

Precipitation

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1938	4.91	2.38	2.42	3.22	4.42	6.30	9.46	3.31	6.00	2.43	2.89	2.80	50.54
1939	2.18	3.79	5.23	4.54	1.29	2.70	0.75	2.14	1.01	4.77	1.14	2.91	32.45
1940	1.68	4.78	3.83	4.58	3.28	1.80	3.17	0.85	2.32	0.76	6.24	2.76	36.05
1941	4.21	1.70	3.40	1.70	2.43	4.29	2.90	1.55	1.18	1.92	2.40	3.19	30.87
1942	3.69	3.45	7.01	1.59	2.11	4.24	4.14	2.09	1.96	2.78	4.89	4.72	42.47
1943	3.74	1.23	4.02	2.64	4.56	1.49	3.91	1.28	1.41	4.82	2.16	0.99	32.25
1944	2.03	2.15	3.92	3.52	0.25	5.35	1.61	1.79	5.36	2.38	5.08	2.83	37.07
1945	3.67	4.09	1.90	2.02	4.47	6.44	2.12	4.27	1.81	2.23	6.86	7.42	47.30
1946	4.18	3.00	1.50	2.62	4.91	2.76	2.22	9.92	2.04	0.34	0.98	3.60	38.07
1947	2.45	1.44	2.30	4.15	4.36	2.88	3.98	2.19	3.95	1.13	5.13	3.95	37.91
1948	5.11	2.08	3.14	2.62	5.37	4.50	4.53	1.24	0.67	4.84	5.16	1.25	40.51
1949	3.21	3.25	1.66	3.23	2.53	0.93	1.10	2.12	6.47	1.60	3.71	1.64	31.45
1950	3.86	3.81	2.99	2.38	1.55	1.10	1.45	3.14	0.89	1.99	6.17	3.37	32.70
#1951	4.04	3.71	4.41	3.06	4.81	4.31	2.13	3.23	2.00	3.98	6.00	4.69	46.97
1952	4.31	4.71	4.41	4.41	3.57	3.26	0.52	6.88	1.13	1.61	1.72	4.09	40.60
1953	6.28	4.14	11.00	6.04	5.06	0.48	2.76	1.81	2.50	4.91	7.06	5.09	57.73
1954	3.26	3.37	3.33	5.25	13.38	2.78	2.50	5.64	8.31	3.58	5.32	5.40	62.32
1955	0.92	4.11	5.42	4.12	0.99	3.52	4.28	17.09	2.40	6.94	5.08	1.03	56.50
1956	6.99	4.36	5.39	2.94	1.85	2.03	3.32	1.46	5.07	4.39	3.46	6.13	47.39
1957	2.47	1.34	3.38	3.78	3.63	1.62	0.64	1.71	0.35	2.67	5.75	6.58	33.92
1958	9.54	5.87	4.48	7.82	4.45	2.98	3.91	5.37	7.50	4.62	3.35	1.78	61.65
1959	2.72	3.45	5.81	4.44	1.24	8.63	8.12	2.93	0.63	4.00	4.20	4.64	51.41
1960	3.04	4.84	3.23	3.51	3.80	3.44	5.18	1.64	5.97	2.48	2.49	4.82	44.46
1961	2.92	4.94	4.71	6.59	4.51	1.67	3.29	3.17	7.04	2.46	3.18	3.36	47.84
1962	3.11	4.16	1.48	3.85	1.86	2.33	1.61	3.72	4.10	8.68	3.80	4.53	43.23
1963	3.13	2.80	4.39	1.48	2.86	1.92	1.72	1.67	3.05	1.25	7.74	3.03	34.84
1964	4.56	4.67	3.48	3.69	0.53	1.91	3.12	1.78	2.65	2.82	2.18	5.08	36.47
1965	2.04	3.17	2.22	2.32	0.93	2.99	0.55	1.48	2.01	1.59	2.08	1.73	23.71
1966	5.29	3.48	1.98	1.24	2.66	3.40	3.21	1.25	3.42	2.62	4.43	3.03	36.01
1967	2.28	4.05	4.67	4.83	7.32	3.46	2.47	5.74	2.00	0.96	3.38	6.42	47.60
1968	3.85	1.15	7.86	1.72	3.26	5.65	0.55	1.63	1.79	1.85	6.74	6.23	42.28
1969	2.26	7.08	2.63	4.37	1.96	0.63	2.98	1.89	4.42	1.64	8.18	9.74	47.78
1970	0.89	4.65	4.32	2.79	3.01	4.62	1.27	4.12	2.60	2.63	4.09	6.92	41.91
1971	1.88	5.05	3.08	2.92	3.72	1.74	2.84	1.59	1.55	2.16	6.74	2.40	35.67
1972	2.05	5.29	5.37	3.34	5.26	6.78	2.19	0.83	5.94	2.98	7.02	6.09	53.11
1973	3.12	2.13	2.20	5.65	3.76	4.68	4.83	2.78	1.95	2.71	1.74	7.20	42.75
1974	3.22	3.24	4.01	3.86	2.87	2.29	1.54	3.41	7.03	3.12	1.73	3.92	40.24
1975	5.70	3.37	2.74	2.40	1.78	2.10	2.35	5.52	5.49	4.41	5.13	4.80	45.79
1976	5.29	2.45	2.42	2.00	1.98	0.35	4.30	7.99	1.56	4.16	0.84	3.35	36.72
1977	4.41	2.40	4.76	4.07	3.52	2.49	2.21	2.91	4.03	4.83	2.34	6.20	44.17
RECORD MEAN	3.80	3.38	3.84	3.56	3.24	3.13	3.15	3.60	3.24	3.24	3.85	3.69	41.52

Snowfall

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
1938-39	0.0	0.0	0.0	0.0	10.0	1.3	7.5	4.7	16.5	0.2	0.0	0.0	40.2
1939-40	0.0	0.0	0.0	0.0	1.0	6.5	4.6	23.8	0.3	1.5	0.0	0.0	37.7
1940-41	0.0	0.0	0.0	T	8.5	4.5	20.4	1.3	13.1	0.0	T	0.0	47.8
1941-42	0.0	0.0	0.0	T	T	0.2	8.2	6.2	7.9	1.5	0.0	0.0	24.0
1942-43	0.0	0.0	0.0	0.0	T	6.8	26.4	4.5	8.0	T	0.0	0.0	45.7
1943-44	0.0	0.0	0.0	0.0	T	0.3	5.1	9.6	12.7	T	0.0	0.0	27.7
1944-45	0.0	0.0	0.0	0.0	1.2	6.9	24.3	26.3	0.5	0.0	T	0.0	59.2
1945-46	0.0	0.0	0.0	0.0	4.9	24.6	9.8	9.8	0.2	1.5	0.0	0.0	50.8
1946-47	0.0	0.0	0.0	0.0	T	4.9	4.0	9.0	0.9	0.6	0.0	0.0	19.4
1947-48	0.0	0.0	0.0	0.0	1.1	26.8	32.5	17.0	11.8	0.0	0.0	0.0	89.2
1948-49	0.0	0.0	0.0	0.0	1.1	5.5	13.7	6.9	9.9	0.0	0.0	0.0	37.1
1949-50	0.0	0.0	0.0	0.0	1.4	2.3	7.9	15.2	5.1	T	0.0	0.0	31.9
1950-51	0.0	0.0	0.0	0.0	T	2.7	13.9	9.2	3.9	0.0	0.0	0.0	29.7
#1951-52	0.0	0.0	0.0	0.0	T	8.4	10.7	19.1	1.4	0.0	0.0	0.0	39.6
1952-53	0.0	0.0	0.0	T	T	2.4	13.6	11.4	0.2	2.2	T	0.0	29.8
1953-54	0.0	0.0	0.0	0.0	T	T	19.2	1.9	0.4	2.1	0.0	0.0	23.6
1954-55	0.0	0.0	0.0	0.0	T	10.3	0.9	6.5	7.0	0.4	0.0	0.0	25.1
1955-56	0.0	0.0	0.0	0.0	2.5	1.8	7.7	14.5	31.2	3.2	0.0	0.0	60.9
1956-57	0.0	0.0	0.0	0.0	0.6	15.4	20.6	2.8	11.5	1.1	0.0	0.0	52.0
1957-58	0.0	0.0	0.0	T	0.1	T	6.6	23.9	12.0	2.1	T	0.0	44.7
1958-59	0.0	0.0	0.0	0.0	0.1	4.6	4.1	10.7	14.6	T	0.0	0.0	34.1
1959-60	0.0	0.0	0.0	0.0	0.6	5.5	10.2	2.3	22.3	T	0.0	0.0	40.9
1960-61	0.0	0.0	0.0	T	T	16.9	18.7	14.9	9.0	2.0	0.0	0.0	61.5
1961-62	0.0	0.0	0.0	T	0.9	11.4	2.5	28.7	1.1	0.1	0.0	0.0	44.7
1962-63	0.0	0.0	0.0	T	0.9	5.3	6.5	4.6	13.6	T	0.0	0.0	30.9
1963-64	0.0	0.0	0.0	T	0.0	17.7	14.4	23.2	7.7	T	0.0	0.0	63.0
1964-65	0.0	0.0	0.0	T	T	12.2	22.2	4.7	9.7	1.6	0.0	0.0	50.4
1965-66	0.0	0.0	0.0	0.0	T	2.3	26.4	12.1	3.3	T	T	0.0	44.1
1966-67	0.0	0.0	0.0	0.0	0.0	9.9	0.5	23.5	22.9	3.3	T	0.0	60.1
1967-68	0.0	0.0	0.0	0.0	2.2	14.7	17.7	3.4	6.8	0.0	0.0	0.0	44.8
1968-69	0.0	0.0	0.0	0.0	0.4	5.1	0.9	41.3	6.1	T	0.0	0.0	53.8
1969-70	0.0	0.0	0.0	T	T	12.6	7.4	10.5	18.2	0.1	0.0	0.0	48.8
1970-71	0.0	0.0	0.0	T	T	27.9	12.0	8.1	7.4	1.9	0.0	0.0	57.3
1971-72	0.0	0.0	0.0	0.0	2.8	7.9	7.8	16.5	12.1	0.4	0.0	0.0	47.5
1972-73	0.0	0.0	0.0	T	0.6	3.3	3.6	2.5	0.3	T	0.0	0.0	10.3
1973-74	0.0	0.0	0.0	0.0	0.0	T	16.0	17.8	0.1	3.0	0.0	0.0	36.9
1974-75	0.0	0.0	0.0	0.0	2.0	3.6	2.2	17.0	1.8	1.0	0.0	0.0	27.6
1975-76	0.0	0.0	0.0	T	0.1	19.3	15.0	1.4	10.8	T	0.0	0.0	46.6
1976-77	0.0	0.0	0.0	0.0	1.0	17.2	23.2	5.9	10.7	T	0.5	0.0	58.5
1977-78	0.0	0.0	0.0	0.0	0.7	5.2							
RECORD MEAN	0.0	0.0	0.0	T	1.2	8.1	12.2	11.8	8.1	0.7	T	0.0	42.1

\# Indicates a station move or relocation of instruments. See Station Location table.

Record mean values above are means through the current year for the period beginning in 1872 for temperature, 1871 for precipitation and 1936 for snowfall. Data are from City Office locations through 1935 and from Airport locations thereafter.

14739 Boston, MA

STATION LOCATION

Location	Occupied from	Occupied to	Airline distance and direction from previous location	Latitude North	Longitude West	Elevation above: Sea level: Ground at temperature site	Ground: Wind instruments	Ground: Extreme thermometers	Ground: Psychrometer	Ground: Telepsychrometer	Ground: Tipping bucket rain gage	Ground: Weighing rain gage	Ground: 8" rain gage	Ground: Hygrothermometer	Sea level: Pyranometer	Remarks
CITY																
Old State House, corner State & Devonshire Sts.	10/20/70	1/09/71		42° 21'	71° 04'	16										Ground elevation approximate.
103 Court Street	1/10/71	8/12/75	600 ft. NW	42° 21'	71° 04'	40										Ground elevation approximate.
Equitable Building Corner Milk & Devonshire Streets	8/12/75	10/01/84	1200 ft. SE	42° 21'	71° 04'	12	172	156	156				162			
Old U. S. Post Office and Courthouse Milk, Devonshire, Congress & Water Streets East Tower	10/01/84	6/07/29	300 ft. NE	42° 21'	71° 04'	17	188	115	115			154	174 154			8 inch rain gage moved from bad exposure atop east tower to west tower, 154 feet above ground on 7/1/91. Marvin Weighing Rain and Snow Gage installed 1/1/98.
Young's Hotel Building Corner City Hall Avenue and Court Street	6/07/29	9/29/33	700 ft. NW	42° 21'	71° 04'	40	165	106	106		96		96			Anemometer atop City Hall Annex, across City Hall Avenue.
New U. S. Post Office and Courthouse Same site as old	9/29/33	6/06/64	700 ft. SE	42° 21'	71° 04'	20	360	337	336		329		328		a335	Observation Program transferred to Airport 1/1/36. a - Added 1/14/44.
U. S. Custom House India and State Streets	6/06/64	Present	1140 ft. NE	42° 22'	71° 03'	12									b157	b - Located atop Boston Building, 1/3 mile West of Custom House. Decommissioned 11/13/68.
AIRPORT																
U. S. Army Hangar No. 1 Boston Airport East Boston	10/15/26	4/01/27		42° 22'	71° 02'	3										Pibal only.
Section F, Army Base South Boston	4/01/27	11/01/27	1-3/4 mi. S	42° 21'	71° 02'		143									Pibal only.
Shack 25 feet South of Commercial Hangar Boston AP, East Boston	11/01/27	7/01/29	1-3/4 mi. N	42° 21'	71° 02'	2	22		4							Pibal only.
Shack 200 feet SW of East Coast Hangar Boston AP, East Boston	7/01/29	5/01/30	1/8 mi. SW	42° 22'	71° 02'	12	24		4							Pibal only to 2/16/30.
Administration Building Boston Municipal Airport East Boston	5/01/30	11/01/45	1/8 mi. NW	42° 22'	71° 02'	12	50	31	31		a3	b31	3			a - Added 1/1/36. b - Added 2/1/38. Official synoptic records began 1/1/36.
Administration Building Boston Municipal Airport East Boston	11/01/45	11/22/51	Same	42° 22'	71° 02'	12	*62	*33	*33		#32	#32	#32			* - Installed on 30 foot instrument tower on roof 9/17/37. # - Gages moved to roof 3/10/44.
Gate No.11, Boutwell Building, Logan Int'l. Airport, East Boston	11/22/51	12/05/63	5/8 mi. E	42° 22'	71° 01'	15	X33	20	20		19	19	18			X - 34 feet to 7/20/54 and 75 feet to 8/23/57.
General Aviation Adm. Building, West Wing, Logan International AP	12/05/63	Present	5/8 mi. W	42° 22'	71° 02'	d15	22	e33 f6	e33 f5		33 f5	33 f5	33 f5	c4		Instrument relocations completed 12/11/63. c - Commissioned on field site 4/1/64. d - 12 feet to 4/1/64. e - Standby status after 4/1/64. f - Effective 8/5/71.

Requests for additional climatic information should be addressed to: Director, National Climatic Center, Federal Building, Asheville, N. C. 28801

Sale Price: 20 cents per copy. Checks and money orders should be made payable to Department of Commerce, NOAA. Remittances and correspondence regarding this publication should be sent to: National Climatic Center, Federal Building, Asheville, N. C. 28801. Attn: Publications.

I certify that this is an official publication of the National Oceanic and Atmospheric Administration, and is compiled from records on file at the National Climatic Center, Asheville, North Carolina 28801.

Daniel B. Mitchell
Director, National Climatic Center

USCOMM-NOAA-ASHEVILLE - 2000

U S DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N C 28801

AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
210

U.S. MAIL

FIRST CLASS

TOWING - DESCRIPTION AND OPERATION

1. General

A. Forward or aft towing (pushing) is normally accomplished through the nose gear axle, using a yoke-type towbar and a towing vehicle.

B. The nose gear towing load, directly forward or directly aft with the towbar parallel to the ground, is limited to 16,200 pounds. The maximum load limit in any turn is 8100 pounds. The towing vehicle should be equipped with a torque converter to minimize acceleration and deceleration loads on the nose gear. Figure 1 shows towbar pull required to tow the airplane over various surfaces.

C. During the towing operation, the vehicle operator must make certain that turning limits of the nose gear are not exceeded. Maximum nosewheel turning angle is 90 degrees either side of center. Turning limits are displayed on the nose gear and nose gear door with red lines visible from the towing vehicle operator's position. During nosewheel towing all turning is accomplished through the towbar. The nosewheel steering control is made inoperative by placing the steering bypass valve in bypass position and installing the steering bypass valve lockpin.

D. If the airplane is off the runway in soft sand, earth, or mud, towing can be accomplished at the main gear. This method of towing is used when conditions such as those above would exceed the towing load limits of the nose gear. Cables or ropes are attached from each main gear to the towing vehicles. When cables are used for towing, it is good practice to attach connecting ropes at frequent intervals to minimize whipping in the event of cable break. The maximum main gear towing load limit, within 30 degrees of directly forward or directly aft, is 12,150 pounds each gear. Steering during main gear towing is accomplished through the nosewheel steering control, when hydraulic power is available.

E. A qualified person shall be stationed in the flight compartment during all phases of towing to watch for hazardous conditions and to stop the airplane using the airplane brakes in the event the towbar breaks or becomes uncoupled. Station wing and/or tail walkers as necessary to insure adequate clearance between airplane and adjacent equipment and structures.

F. It is desirable to establish some form of communication between the towing vehicle operator and person in the flight compartment; either two way radio (walkie-talkie) or through the airplane interphone system. Electrical power for airplane lights, radio communication with the control tower, hydraulic power and interphone communication may be furnished by the auxiliary power unit (APU).

FILMED

8-8